PREDICTION OF UNIT VALUE OF UN-IMPROVED PARCELS OF HARRIS COUNTY, TEXAS USING LEED SUSTAINABLE SITES CRITERIA OF PUBLIC TRANSPORTATION ACCESS

A Thesis

by

BHAGYASHRI BHARAT JOSHI

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2009

Major Subject: Construction Management

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Approved by:

Chair of Committee,	Paul Woods
Committee Members,	Russ Peterson
	Jesse Saginor
	Michael Speed
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ABSTRACT

Prediction of Unit Value of Un-Improved Parcels of Harris County, Texas Using LEED Sustainable Sites Criteria of Public Transportation Access. (December 2009)

Bhagyashri Bharat Joshi, B.E., L. D. College of Engineering, Ahmedabad, India

Chair of Advisory Committee: Dr. Paul K. Woods

Leadership in Energy and Environmental Design (LEED) is one of the environmental assessment tools available to gauge buildings. This rating system is a voluntary system which does not include financial aspects in the evaluation framework. This poses a challenge for encouraging land development projects, since developers consider financial or economic return as a crucial factor before building a project. It becomes essential to know if market really accepts the economic worth of LEED ratings. This research attempted to find out relationship between economic worth of a land and parameters (measurements), which are essential to earn LEED sustainable rating for public transportation access. To find out this relationship and to recognize power of the LEED measurements to predict the appraised value of a land (dollars per square foot) various statistical models were used and predictive equations produced.

The observational units were properties in Harris County, Texas that were unimproved and had zero improvement value. The dependent variable was unit value of the property measured in dollars per square foot. The independent variables were measurements that are required for a parcel to earn LEED sustainable site rating for public transportation access and the area of parcel.

Data regarding appraised values and land area were acquired from the Harris County Appraisal District and transportation data was obtained from Houston- Galveston Area Council.

Multiple regression analysis was used to analyze different models and to develop predictive equations.

Findings suggest that LEED green building rating system influences the appraised value, dollars per square foot, of properties. It further implies that market considers the economic effect of the LEED rating system even if this assessment method does not explicitly include financial aspects in the evaluation framework.

Findings of this research also suggest that a sustainable feature of a site is related to the economic worth of a related land development project. This will provide encouragement for new sustainable land development projects. This will provide an economic incentive to the owners and developers. Developers will get encouragement to select a site located closer to mass transit networks.

DEDICATION

I dedicate this thesis to my parents and fiancé. Without their patience, understanding, support, and most of all their love, completion of this work would not have been possible.

ACKNOWLEDGEMENTS

I would like to thank my committee chair, Dr. Woods, and my committee members, Dr. Peterson, Dr. Saginor, and Dr. Speed, for their guidance throughout the course of this research.

Thanks also go to my friends and the department faculty and staff for making my time at Texas A&M University a great learning experience.

Finally, thanks to my family for their encouragement and support and to my fiancé for his love and patience.

NOMENCLATURE

GIS	Geographic Information System
HCAD	Harris County Appraisal District
HGAC	Houston – Galveston Area Council
LEED	Leadership in Energy and Environmental Design
LEED-NC	Leadership in Energy and Environmental Design for New Construction
TX	Texas
USGBC	United States Green Building Council

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CHAPTER I

INTRODUCTION

Research Objective

The aim of this study was to predict the appraised values (in dollars per square foot) of unimproved parcels in Harris County, Texas based on the LEED sustainable rating for Public Transportation Access.

Population of interest was parcels, which were within a perimeter described by a distance of one mile outside of Beltway 8 encircling Houston, Texas. Parcels, randomly selected, were unimproved. As specified by the Harris County Appraisal District, these parcels had zero improvement value. Each parcel served as an observational unit based on which the data was collected and analyzed. Theme of this research was quantitative and the data gathered was analyzed using appropriate statistical tools.

Definitions

Parcel: Parcel of land means any area of land in the city under private ownership as shown on the last assessor’s roll of the county or the records of the city, whichever is the

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This thesis follows the style of *International Journal of Construction Education and Research*.

the most recent, or any area of land under legal control of any person.

Appraisal District Office: The sole authority in Texas for the assessment and assignment of value to property for the purpose of taxation. (One of the assumptions of this research study was that assessed taxable value was a reasonable measure of actual value of properties included.)

Improvement Value: The value, in US dollars, assigned to a structure, or building, by the Appraisal District Office in the county where the property is located. (Properties with zero improvement value were included in this study. Hence, no building or structure was constructed on these properties, they were solely vacant properties.)

Unit Value of Unimproved Property: The value, in dollars per square foot, for a given unimproved property. The land associated with a property is assessed and assigned a separate value of its own called land value. Unit value thus could be calculated using land value and area available from Appraisal District Office in the county where the property is located. This study used unit value of properties to facilitate comparison.

Control Group: A control group is a baseline group that receives no treatment or a neutral treatment. For this research study parcels, which did not meet LEED criteria for public transportation credit, formed the control group.

Treatment Group: It is the group, which receives the treatment, and the results are then compared to the results of control group. For this study parcels, which met LEED criteria for public transportation credit, formed the treatment group.

Research Hypothesis

The specific aim of this research study was to identify a relationship between sustainable rating (in terms of public transportation access) of sites and there unit values. Measurements required for a parcel to be qualified for a LEED credit were used as variables for this study. Different statistical models with different independent variables were tested. Common hypothesis that was tested for these models was that some relation between sustainable rating and unit values of sites existed and that they were not unrelated.

Statistically speaking the following hypothesis was tested for each model:
Research hypothesis: Model is statistically significant and that the unit value of a parcel can be predicted by independent variable/ variables.

Following two models were used to test this hypothesis.
Model 1: This model tested the predictability of unit value of a parcel using the area of parcel, number of bus stops and number of rail stations that met LEED criteria for that parcel. This model was used only for those parcels that qualified for LEED credit.

Unit Value of a parcel=β_0 + β_1 (Number of bus stops for a given parcel that met LEED criteria) + β_2 (Number of rail stations for a given parcel that met LEED criteria) + β_3 (Area of parcel) + ε

Model 2: Since it is required for any parcel to have public transportation access within a specified distance to be qualified for the LEED rating, it was essential to determine relationship between unit value of parcel and distance of public transportation access points. This model thus tested the predictability of unit value of parcel using the area of parcel, minimum distance of bus stop and that of the rail station from the centroid of that parcel. This model was used for all 300-sample parcels.

Unit Value of a parcel=β_0 + β_1 (Minimum distance of bus stop) + β_2 (Minimum distance of rail station) + β_3 (Area of parcel) + ε

Limitations

Only unimproved properties in Harris County, Texas that had zero improvement values as defined by Harris County Appraisal District data were included in this research.

Only parcels in Harris County, Texas not exempted from tax as defined by Harris County Appraisal District data were included in this research study.

Only data from Harris County Appraisal District and Houston-Galveston Area Council were used to construct the data base spreadsheets for the dependent and independent variables.

Harris County Appraisal District data is updated on quarterly basis. Data for this research was obtained for the first quarter of the year 2009. For properties where 2009 appraised value was not available 2008 data was used.

Only existing light rail transit networks for the Harris County were used in this research study.

Population of samples considered for this research study was located within a perimeter described by a distance of one mile outside of Beltway 8 and within the city limits of Houston, Texas.

LEED credit for public transportation access requires to measure distance from the entrance of a building. Since unimproved properties with no building or improvement were considered for this research study, distance to transit points was calculated from the centroid of properties.

This research study focused only on the LEED credit for alternative transportation-public transportation access, which falls under the category of sustainable sites. Findings of this research and their interpretation strictly adhere to the LEED credit for public transportation access.

Delimitations

This research study and its findings are meaningful only for unimproved properties. These properties should have no improvement or development on them. Research findings are not applicable to improved or developed properties.

This research study and its findings are applicable to unimproved properties in the Harris County Appraisal District only. So, findings and predictive equations developed in this research study cannot be used for different locations.

This research study was delimited in terms of the variables of interest identified. Five independent variables were considered to predict the variation in the dependent variable. These variables were distance to nearest bus stop, distance to nearest light rail station, number of bus stops that met LEED criteria for a given parcel, number of light rail stations that met LEED criteria for a given parcel and area of parcel. The time period for data gathering and analysis was delimited to five months and hence many other relevant variables were not utilized.

Unit value, measured in dollars per square foot, of the unimproved parcel was considered as a dependent variable for this research study and not the appraised value, dollars. Predictive equations developed in this study were developed strictly for the unit value of parcels.

Assumptions

The first assumption: The LEED-NC green building rating system will continue to be a practical and meaningful assessment tool for gauging sustainability features of buildings.

The second assumption: The data used in this research are accurate. They consist of public records, collected and updated regularly. There are no apparent means of verification.

The third assumption: Appraised value is a reasonable indicator of true or actual value.

The fourth assumption: Variables used in this research are identifiable and relationships are measurable.

Importance of Research

In 2000, U. S Green Building Council (USGBC) released a rating system called the

Leadership in Energy and Environmental Design (LEED) green building rating system for New Commercial construction and major renovations or LEED-NC. This rating system along with focusing on the building operational and maintenance issues, addresses the different project development/ delivery processes that exist in the US building design and construction market (USGBC, 2005).

LEED is a nationally accepted benchmark for the design, construction and operation of high performance green buildings (USGBC, 2009). LEED is one of the environmental building assessment methods available to gauge buildings (Ding, 2008).

The USGBC-LEED Green Building Rating System is a voluntary system, which is based on the existing proven technology. This rating system is consensus-based and market-driven. The rating system is organized into five environmental categories: Sustainable Sites, Water Efficiency, Energy & Atmosphere, Materials & Resources, and Indoor Environmental Quality. This rating system is a performance-focused system. Credits can be earned for satisfying criteria that address environmental impacts, which are an integral part of the design phase, construction phase and also Operation& Maintenance of buildings (USGBC, 2005).

With this rating system it is possible to make decisions regarding land development/restoration projects, which limit the environmental impact on the regional ecosystem. Green design includes elements, which are environmental, economical, and social that eventually benefits the society at large. This includes building stakeholders, which are essentially the owners, occupants and the general public (USGBC, 2005).

In LEED version 3.0 (USGBC, 2008) for new construction and major renovations for commercial premises, buildings may qualify for four levels of certification.

• Certified: 40-49 points

• Silver: 50-59 points

• Gold: 60-79 points

• Platinum: 80 points and above

Points for each of the five categories have been distributed as follows:

- Sustainable sites (26 possible points)
- Water efficiency (10 possible points)
- Energy and atmosphere (35 possible points)
- Materials and resources (14 possible points)
- Indoor environmental quality (15 possible points)

In addition to these major categories, two more categories have been included in the newest version of LEED.

- Innovation in design (6 possible points)
- Regional Priority (4 possible points)

Credit points for sustainable sites could be further broken down into the following levels:

- Construction Activity Pollution Prevention Plan (pre-requisite)
- Site selection (1 pt)
- Development density and community connectivity (5 pt)
- Brownfield redevelopment (1 pt)
- Alternative transportation availability:
    - Public transportation access (6 pt)
    - Bicycle storage and changing rooms (1 pt)
    - Low-emitting and fuel-efficient vehicles (3 pt)
    - Parking capacity and carpooling (2 pt)
- Site Development:
    - Protect or restore habitat (1 pt)
    - Maximize open space (1 pt)
- Storm water Design:
    - Quantity control (1 pt)
    - Quality control (1 pt)
- Heat island effect:
    - Non-roof (1 pt)
    - Roof (1 pt)
- Light pollution reduction (1 pt)

This research focused on the credit point earned by satisfying the public transportation access criteria, which falls under the sustainable sites category as per this voluntary standard.

LEED Credit for Sustainable Sites-Public Transportation Access as per LEED-NC Version 3.0 (USGBC, 2008) has following aspects.

Intent: Reduce pollution and land development impacts from automobile use.

Requirements:

Locate project within ½ mile walking distance (measured from a main building entrance) of an existing- or planned and funded- commuter light rail, light rail or subway station.

OR

Locate project within ¼ mile walking distance (measured from a main building entrance) of one or more stops for two or more public or campus bus lines usable by building occupants.

It has been found that ecosystems surrounding buildings are affected by the options occupants have for travelling to and from the site. Occupants either travel using their private automobiles or if mass transit networks are available at convenient distance they travel using these networks. Vehicle use in America has nearly tripled in terms of miles per year between 1970 and 2002(BTS, 2002). Vehicle fuel consumption and emissions have been found detrimental to human health. These emissions cause change in the climate along with increasing particulate pollution. Considering all these factors LEED with its standards encourages developers to give preference to those buildings which have got location attribute such that existing neighborhoods, transportation networks and urban infrastructures could be enhanced (USGBC, 2005).

With the reduction in the use of private vehicles, environmental pollution can be significantly reduced. Public transportation has been found to be approximately twice as fuel efficient as private vehicles when passenger miles travelled is considered. If site is selected in such a way that the existing transportation networks can be conveniently accessed then the need for new transportation lines can be minimized. This will in turn reduce down the pressure on local transportation authorities of a region. Also, it has been documented that many occupants take proximity to mass transit as a benefit. This will influence both the value and marketability of the building providing incentives for the owners (USGBC, 2005).

LEED like various assessment tools available does not include financial aspects in the evaluation framework. This might contradict the final goal of a development project. Developers consider financial or economical return as a crucial factor before building a project. This might be because even if project is environmentally sound but if it is very expensive to build, then developer’s fundamental goal of economic return will not be achieved. This will make project less attractive in the eyes of the developers even though it may be environmentally friendly (Ding, 2008).

With this understanding it becomes important to know if there exists a relationship between the LEED ratings and the economic worth of the building. And if yes, then how meaningful is that relationship. It is also essential to understand whether the LEED ratings are accepted by the market and have got any economic importance in the eyes of the developers.

Since the focus of this research was on the credit point earned by meeting the sustainable site criteria for public transportation access, the economic worth of a land was considered. Specifically the spotlight of this research was to find a meaningful relationship between the economic worth of a land and the measurements (parameters), which are essential to earn LEED Public Transportation Access rating. To find out this relationship and to recognize power of the LEED measurements to predict the appraised value of a land (dollars per square foot) various statistical models were used and analyzed.

If suggested model/models indicate a significant relation between unit value (dollars per square foot) of a land and the LEED rating then it will show that the market accepts the economic value of the LEED. Like mentioned earlier this will be a good incentive for owners. If the sustainable rating of a site is related to the economic worth of related land development project then it will provide encouragement for new sustainable land development projects. This will comply with dual goals of sustainability of land development/ restoration projects, which are increased economic returns, and preservation of the environment.

If the suggested model/models fail to establish a relationship between unit value and the LEED rating then it may prove difficult to encourage new sustainable land development projects for purely economic reasons. Also, if there is no such relation then developers will not consider public transportation access as one of the priorities while planning a project.

CHAPTER II

LITERATURE REVIEW

Awareness towards sustainability and environment has lead to the emergence of various voluntary standards for buildings such as LEED (USA). These standards are market driven and serve as environmental building assessment methods. For these approaches to be viable as well as successful it is essential to find out if prices of buildings truly incorporate environmental costs and benefits. “Green buildings” have gained lot of popularity in some sectors of the economy in response to the pricing signals. Little empirical evidence is available to prove that commercial real estate prices incorporate sustainability characteristics despite widely popularized financial and environmental benefits. Unfortunately, very few studies have attempted to gauge price effects of green building ratings (Fuerst and McAllister, 2008).

Various perspectives have been contemplated to answer questions like “Why do organizations adopt voluntary, environmental standards?” and “What is the societal value of such standards?” Organizations might be motivated to adopt innovations, including voluntary standards because they want to be recognized for their commitment to the environmental issues in their industry. They might want to communicate something about their practices to the outside world, including regulators, customers, the public, etc. On the other hand, adoption may be driven by the pursuit of elemental benefits, meaning that the organization anticipates actual economic and/or environmental benefits that are a direct result of the standards, regardless of perceptions in the outside world (Corbett & Muthulingam, 2007).

USGBC, through its publication LEED for New Construction Version 2.2, presents sustainable site guidelines and encourages using these metrics to make decisions regarding land development in terms of sustainability (USGBC, 2005). Like mentioned earlier, this rating system helps to make decisions regarding land development/restoration projects in such a way that the local ecosystem is preserved. Sustainability of land development/restoration projects provides increased economic value while preserving the environment. Unfortunately, there are very few studies which attempt to understand the economic worth of this voluntary rating system. This paper focused on identifying the relationship between the LEED sustainable rating (Public Transportation Access) and the economic worth of the land. If, there is no meaningful relationship between these variables then it may be difficult to justify the motivation of organizations which adopt these voluntary standards. Moreover, it will be difficult to encourage sustainable land development/restoration projects for economic reasons.

Sales price information is difficult to gather. Also, infrequency of sales makes the parcels incomparable on a value basis. This infrequency makes it difficult to know the amount at which any given land will transact at any given time (Rappaport, 2007). Hence, appraised value of parcels appeared to be the best alternative to make meaningful comparisons.

"No two houses are the same. The specific combination of attributes, both locational and physical, associated with any building determines that building's quality" (Rappaport 2007, p.42). Heterogeneity among buildings makes comparisons difficult if not impossible. So, for this research only un-improved land with zero improvement value was considered.

Houston, Texas is ranked as the fourth most populous city in the United States (City of Houston, 2009). Since 1999 Houston has alternated its position with Los Angeles for being most polluted city of United States (NASA, 2007). Along with pollution caused by the petrochemical and power plants Houston faces severe pollution caused by automobiles. The prime reason being the congested highways, which in turn is a result of an enormous population-growth in the last decade. According to U.S Census Bureau (2000) statistics population of Houston has increased by 19.7% from 1990 to 2000. People are forced to move out to the surrounding suburbs at an ever-increasing distance in search of affordable housing. As a result, the city's population is facing increasingly longer commute between home, work and leisure. On the account of this Houston is now spread out over a significant area. This poses a challenge for authorities, which are responsible for implementing measures to reduce pollution.

According to U.S. Census Bureau (2000) data, mean travel time to work is 27 minutes. This data also shows that 77.8 % drove alone and 12.7 % car-pooled with private automobiles. This has put local government under constant pressure to keep the infrastructure, such as highways, roads, public transit, etc on a satisfactory level. New highways are under construction and more road lanes are added to existing highways to meet the current need of the public and to keep up with the future increase in the capacity. U.S Census data also reflects that people are more comfortable using their private automobiles than the existing mass transit system. This might be because the existing transit facilities are not that efficient or that they have limited connectivity. Local authority will have to consider setting up an efficient alternative mass transit system though costly to reduce ever-increasing pollution caused by automobile use. Therefore, LEED encourages developers to select sites that have got convenient access to the mass transportation networks (USGBC, 2005).

Houston has the largest area, 618 square miles, of all the major US cities. Houston is the Texas state's largest city in terms of population, size and number of persons per square mile. Between 1990 and 2000, Houston had a very small (1.2%) increase in owner occupied units. Also, the housing value increased by 1.05% from 1990 to 2000 (City of Houston Planning and Development Department, 2008).

The pie-chart (see Figure 2.1) presents Land use distribution in the City of Houston. In 2000 vacant and undeveloped land accounted for 24% (i.e. 91,370 acres) of the total land use in the city. This largest single land use classification is followed by single-family residential use.

Almost 1/3rd of the City's vacant land is located south of Loop 610 accounting for 29,008 acres in total. Vacant land inside Loop 610 is comprised of small parcels distributed with mixed uses. Vacant parcels located towards the city boundaries tend to be large, discontinuing the patterns of urbanization (City of Houston Planning and Development Department, 2008). This land use pattern was significant to understand since this research study included only vacant parcels.

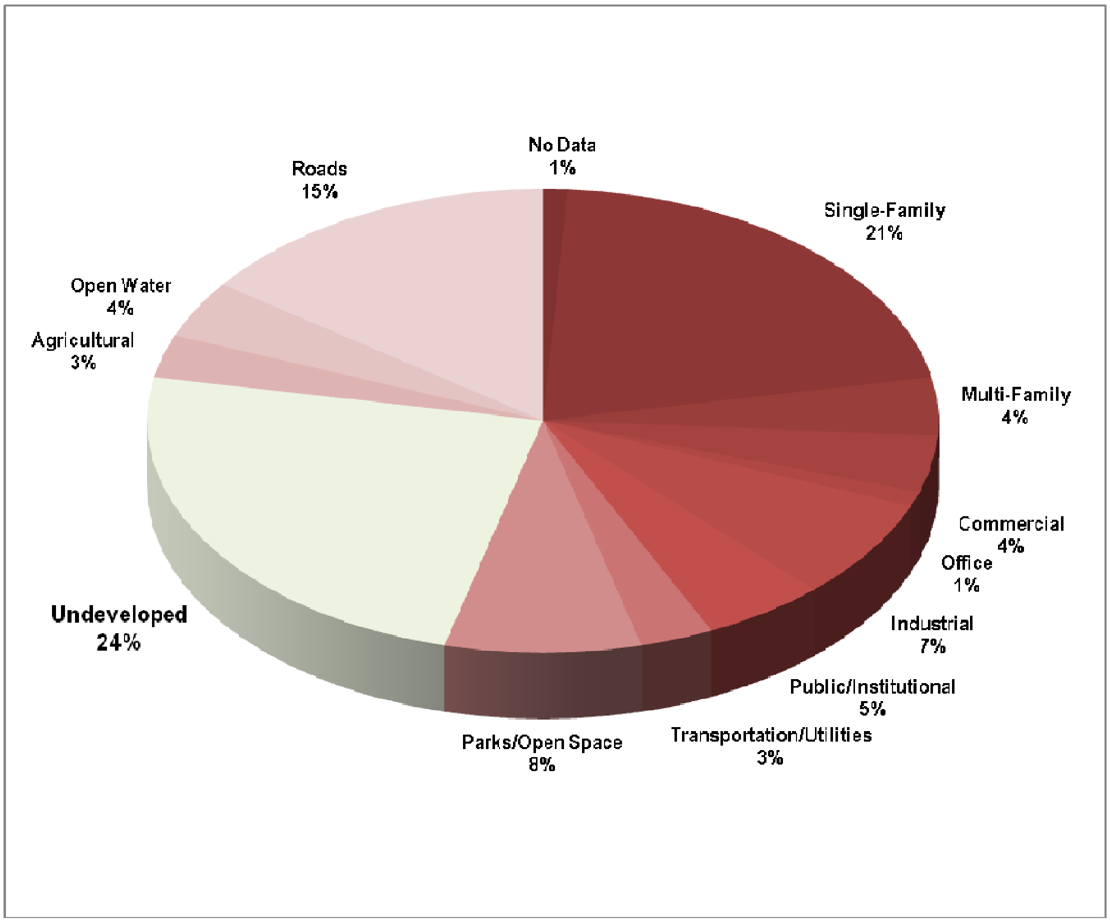


Figure 2.1: Land Use Distribution in the City of Houston

Source: (City of Houston Planning and Development Department, 2008)

CHAPTER III

DATA COLLECTION

Population of Interest

The population of parcels was located within a perimeter described by a distance of one mile outside of Beltway 8 encircling and within the city limits of Houston, Texas.

To validate the results and to recognize true relationship between the appraised value of land and the sustainable rating the population of interest were parcels, which were un-improved.

As per Harris County Appraisal Data, parcels with zero improvement value were considered unimproved. All these parcels formed the population for this research study. Figure 3.1 graphically depicts the population extent for this research study.

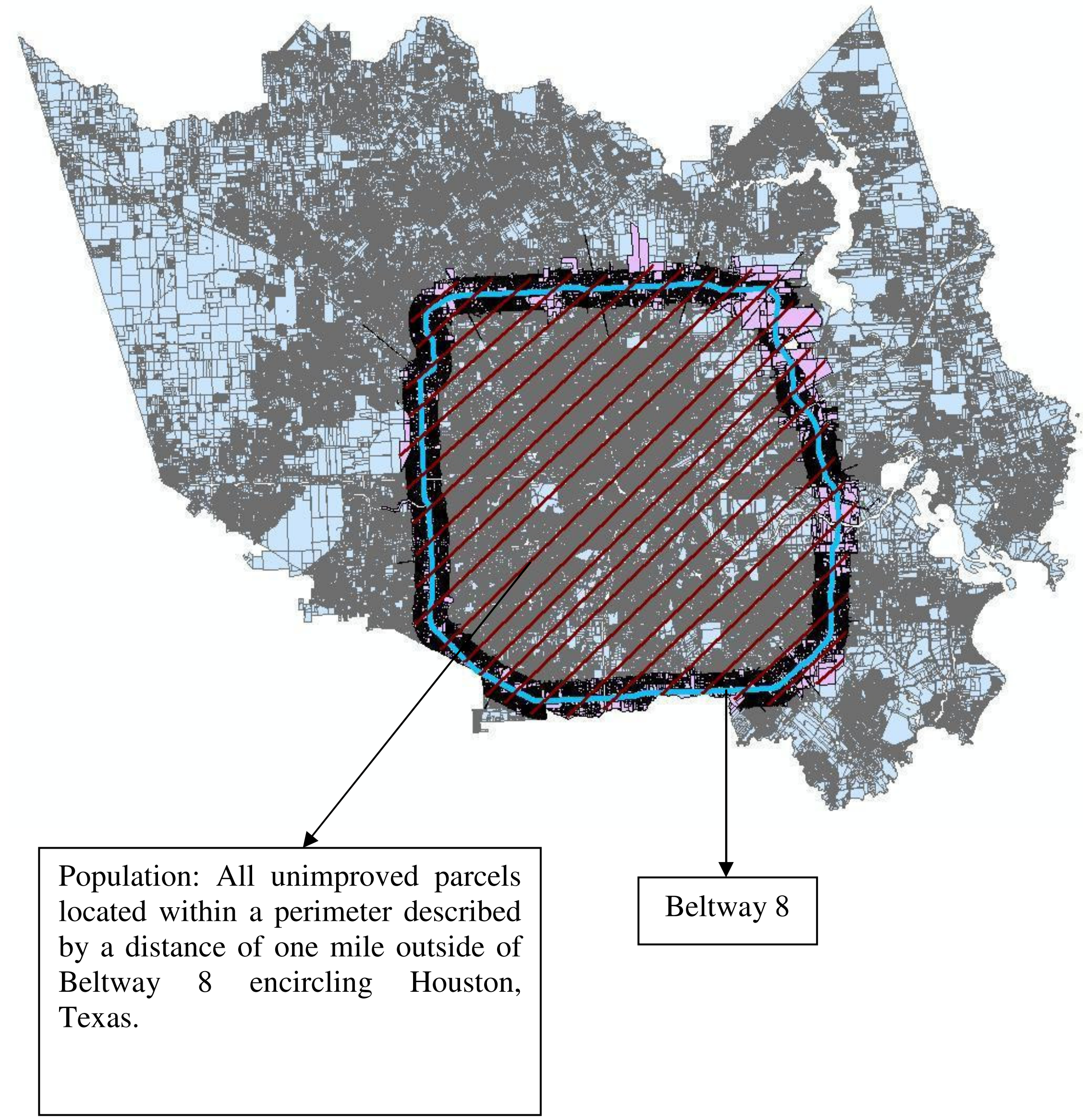


Figure 3.1: Geographical Location of Population and Beltway 8

Sample Selection

From population of unimproved parcels, all parcels that met LEED criteria of public transportation were listed. A random selection of 150 parcels, which qualified for LEED rating for Public Transportation Access, was made. These parcels formed the treatment group. Figure 3.2 explains this step in detail.

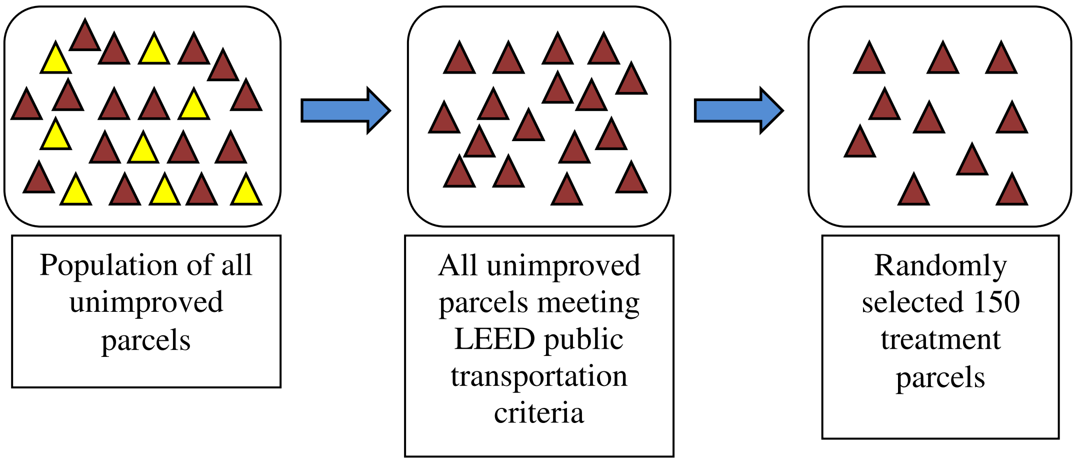


Figure 3.2: Block Diagram Representing Process of Random Selection of Treatment Sample Parcels

Likewise, 150 paired parcels, which did not qualify for LEED rating, and were located in the vicinity of each parcel of treatment group, were selected. These parcels were a part of control group for analysis purposes. Figure 3.3 explains this step in detail.

Therefore a total of 150 pairs of properties were selected for this study. Half of them qualified for the LEED Public Transportation Access rating and the other half did not.

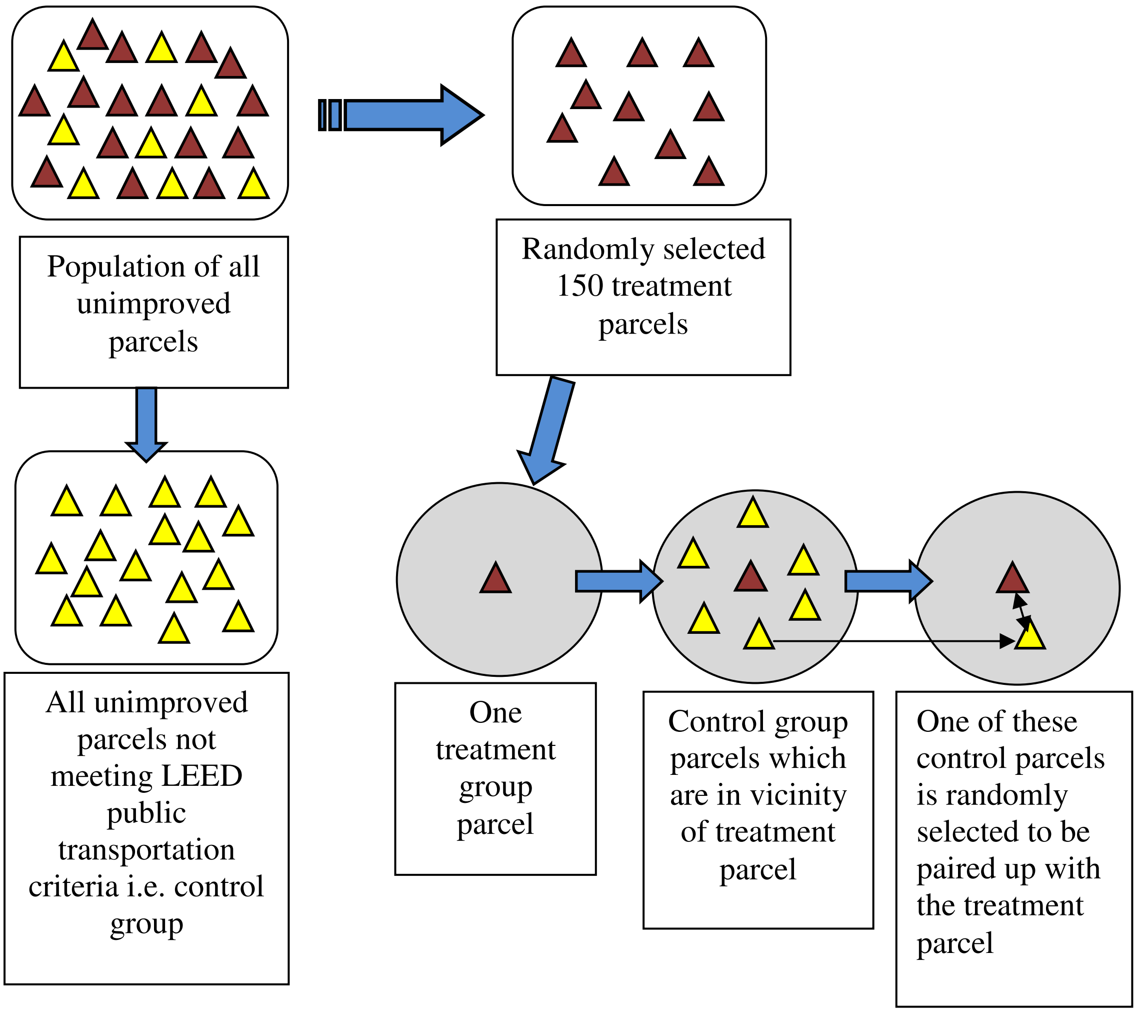


Figure 3.3: Block Diagram Representing Process of Randomly Selecting Paired Control Group Parcel for a Treatment Parcel

Data Collected

Following models were analyzed and compared using statistical tools. For each model different population parameters were estimated.

Model 1: This model had one dependent variable; Appraised value/ Square foot of a parcel and following were the independent variables which were considered as the predictors of the dependent variable:

1. Independent Variable 1: Number of Bus stops which met the LEED criteria
2. Independent Variable 2: Number of Rail stations which met the LEED criteria
3. Independent Variable 3: Area of parcel, measured in square feet

Here the hypothesis tested was that this model was statistically significant and was capable of predicting the appraised value per square foot of the parcel using the independent variables.

Appraised Value/square foot of a parcel=$\beta_0 + \beta_1$ (Number of bus stops for a given parcel that met LEED criteria) + β_2 (Number of rail stations for a given parcel that met LEED criteria) + β_3 (Area of parcel) + ε

β_0 = intercept, appraised value per square foot of a parcel when neither bus stops nor rail stations met the LEED criteria

β_1 = partial slope for number of bus stops or expected change in appraised value per square foot of a parcel when one more bus stop which met LEED criteria was added to the parcel while controlling other independent variables

β_2 = partial slope for number of rail stations or expected change in appraised value per square foot of a parcel when one more rail station which met LEED criteria was added to the parcel while controlling other independent variables

β_3= partial slope for area of parcel

ε = error

This model was used for 150 treatment group parcels since it included number of bus stops and rail stations which were within qualifying LEED distances.

Model 2: This model had one dependent variable; appraised value per square foot of a parcel and following were the independent variables which were considered as the predictors of the dependent variable:

1. Independent variable 1: Minimum distance of bus stop, measured in miles
2. Independent variable 2: Minimum distance of rail station, measured in miles
3. Independent Variable 3: Area of parcel, measured in square feet

Appraised Value/square foot of a parcel=β_0 + β_1 (Minimum distance of bus stop) + β_2 (Minimum distance of rail station) + β_3 (Area of parcel) + ε

β_0 = intercept

β_1 = partial slope for the minimum distance of bus stop controlling other independent variables

β_2 = partial slope for the minimum distance of rail station controlling other independent variables,

β_3= partial slope for area of parcel

ε = error

This model was used for 150 paired parcels i.e. 150 treatment group parcels and 150 corresponding control group parcels.

Collection Method

Population Mapping

The population of parcels was located within a perimeter described by a distance of one mile outside of Beltway 8 encircling Houston, Texas. Following steps were taken to collect data about the population considered.

Boundary of Harris County: Boundary of Harris County was projected on Arc Map GIS using Harris County Appraisal District, County shape file. This shape file defined Harris County boundary as well as provided information about the area of Harris County. Figure 3.4 provides a GIS presentation of Harris County boundary.

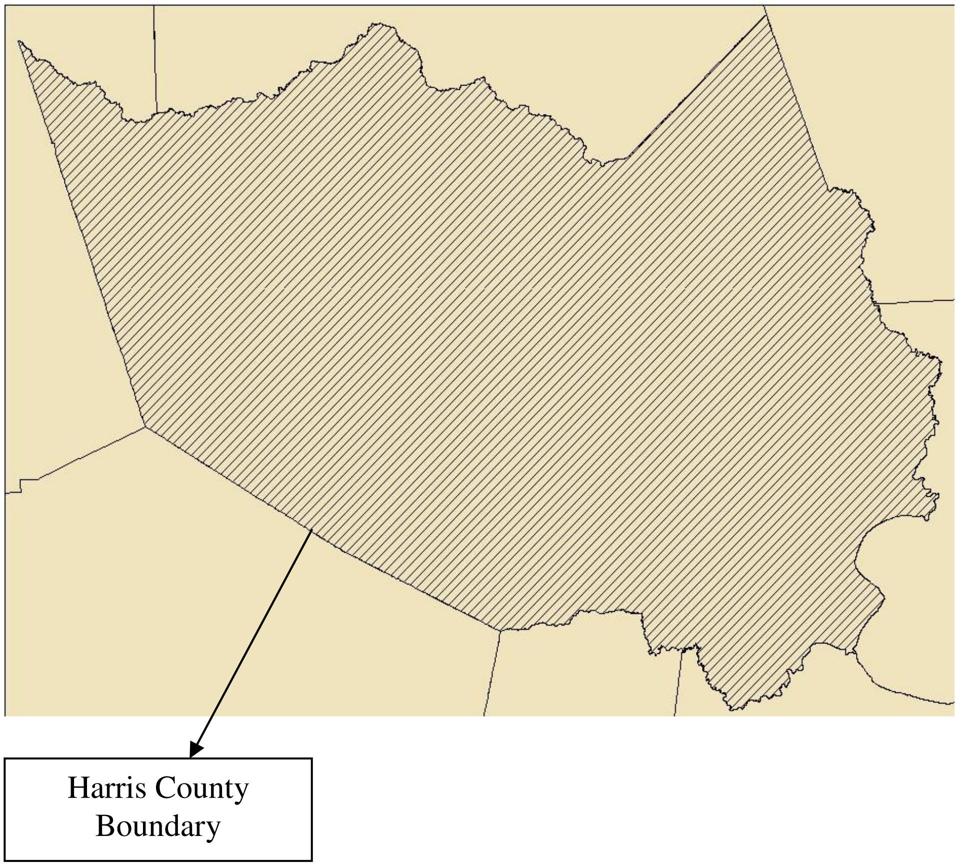


Figure 3.4: GIS Presentation of Harris County Boundary

Location of Beltway 8: Harris County Public Infrastructure Department Highways shape file was then projected on Harris County boundary file on Arc Map GIS. Location of beltway 8 was then marked using appropriate GIS functions. Figure 3.5 is a GIS representation of beltway 8.

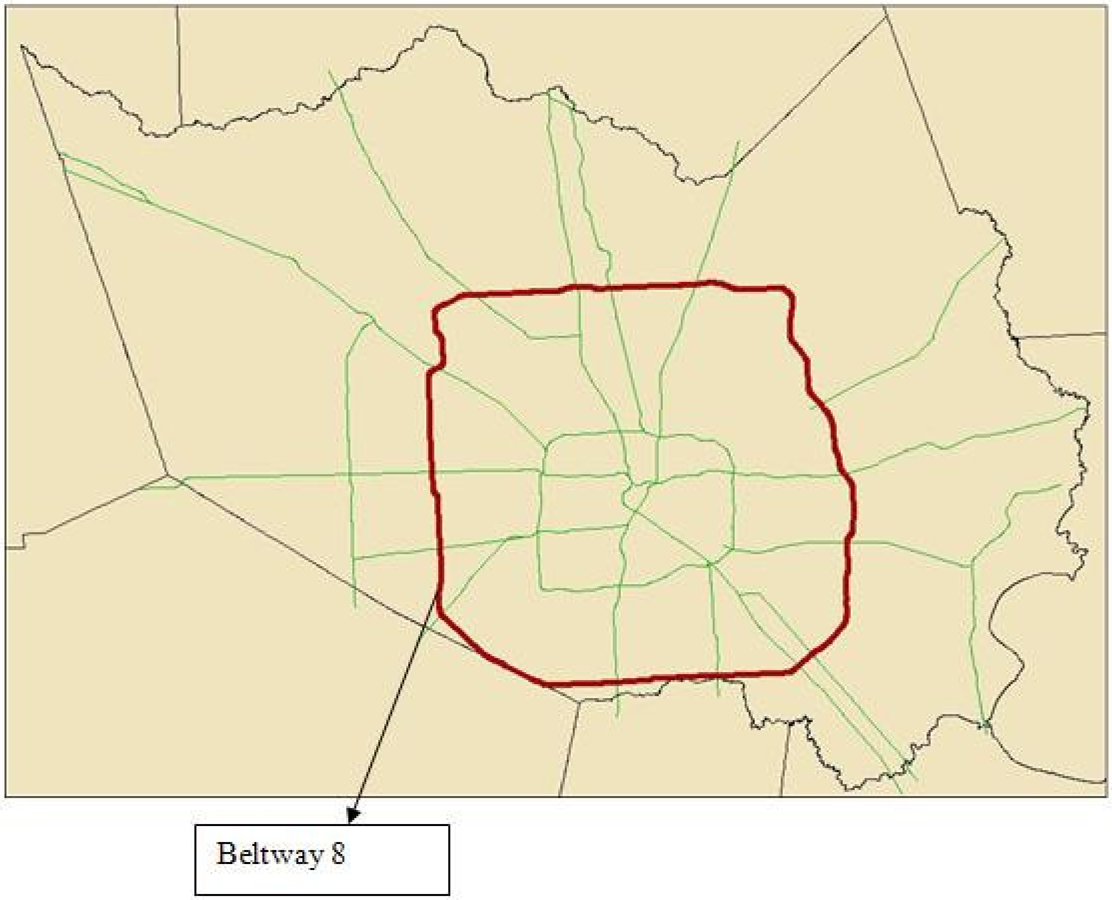


Figure 3.5: GIS Presentation of Beltway 8

Defining population boundary: Parcels shape file available from Harris County Appraisal District was then projected on Arc Map GIS. This shape file included information regarding 13- digit parcel ID, parcel boundaries, physical address and location of each parcel. Figure 3.6 presents parcels as projected on the GIS map.

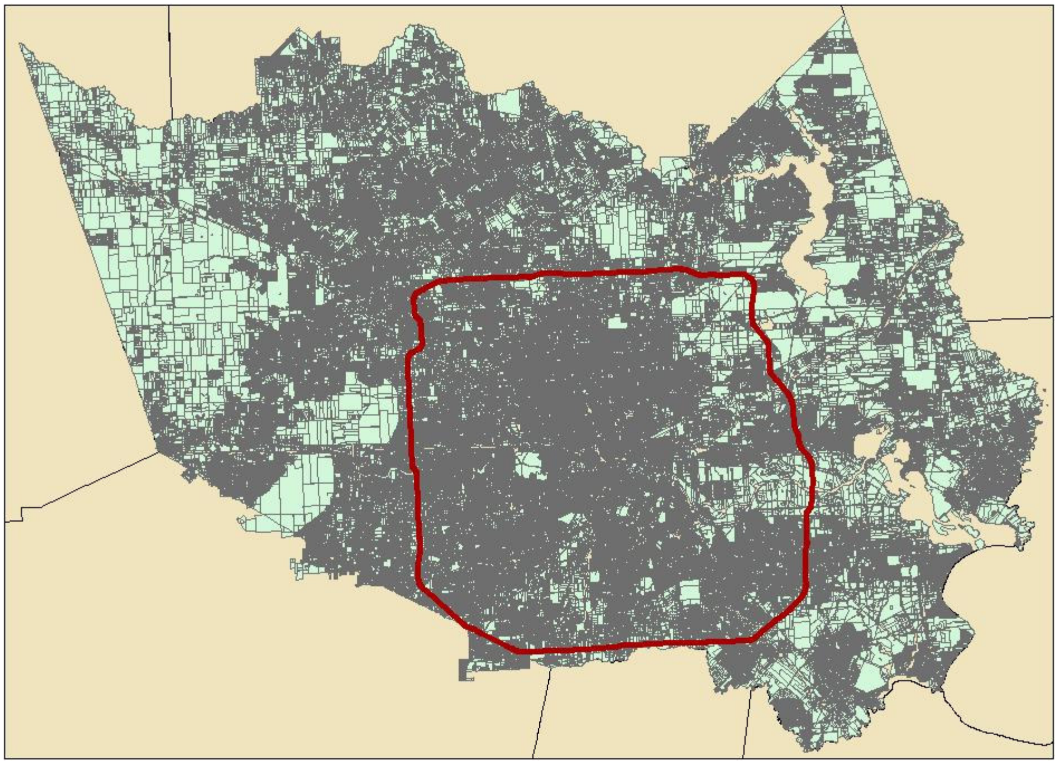


Figure 3.6: Parcels Projected on GIS Map

Selection of parcels located within perimeter described by a distance of one mile outside of Beltway 8 encircling Houston, Texas: Using appropriate GIS tools all parcels which were located within the specified perimeter were selected. This provided data of all parcels within the specified perimeter along with there parcel ID, boundary, address and location.

Population: Appraised values of all the parcels selected in previous step were recorded using Harris County Appraisal District data. For collecting this information 13-digit parcel ID was used and appraised value was retrieved. All parcels, which had zero improvement value, were then listed. This list thus formed the population of all parcels with zero improvement value. This population so obtained was considered for this research study. Figure 3.7 illustrates zero improvement value for a parcel as retrieved from HCAD website.

Valuations					
2008 Value			2009 Value		
	Market	Appraised		Market	Appraised
Land	225,250		Land	225,250	
Improvement	0		Improvement	0	
Total	225,250	225,250	Total	225,250	225,250
5-Year Value History					

Figure 3.7: Zero Improvement Value for a Parcel Obtained from HCAD Website

Geographical Presentation of Public Transit Points

GIS file containing all population parcels was then projected on Arc Map. Transportation maps of bus stops and light rail stations were obtained from Houston-Galveston Area Council (HGAC). These maps were then layered over the population map. This defined the location of all bus stops and light rail stations with respect to the population considered. Figure 3.8 illustrates this procedure graphically.

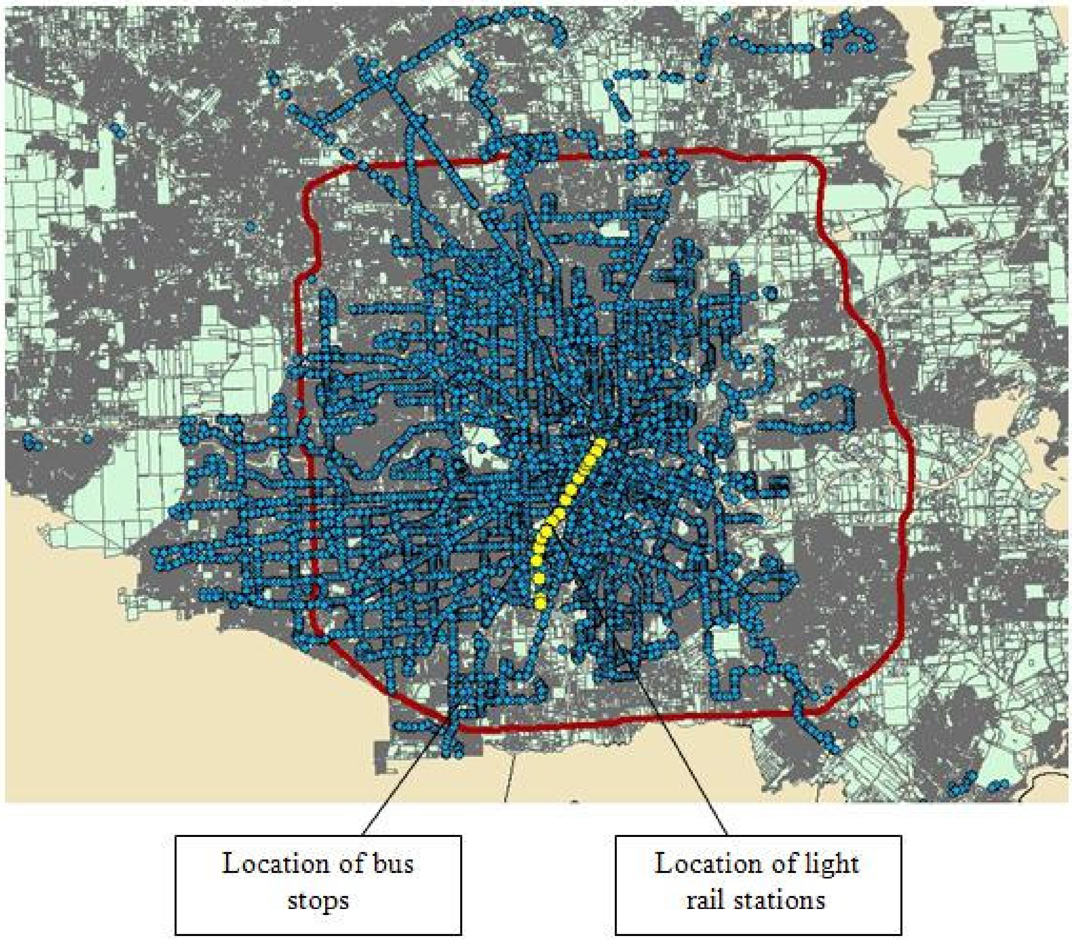


Figure 3.8: Bus and Light Rail Station Maps Layered on Parcels Map in GIS

Selection of Treatment Group

Following steps were taken to select treatment group.

Selection of all parcels meeting LEED criteria of public transportation: Using buffer function of GIS, parcels which were within quarter mile distance (measured from centroid of parcel) from bus stops and/or half mile distance from light rail stations were selected. Figure 3.9 is a pictorial presentation of this procedure. All these selected parcels met LEED criteria of public transportation.

While collecting data it was found that few of the parcels which qualified for LEED credit had both bus stop and light rail stations within qualifying distances i.e. both bus stop and light rail station were located within quarter mile and half mile distance respectively from the parcel. And the rest of the parcels either met bus stop distance criteria or the light rail distance criteria. So, three groups of LEED qualifying parcels were formed for the ease of analysis.

First group consisted of all parcels, which had both bus stops and light rail stations within qualifying distances. Second group had all the parcels, which were located within quarter mile of bus stop. And the third group had all parcels, which were located within half mile of light rail station.

Random selection of 150 treatment group parcels: From each of the three groups formed 50 parcels were randomly selected. Thus, in total 150 parcels were randomly selected. This formed the treatment group for this research study.

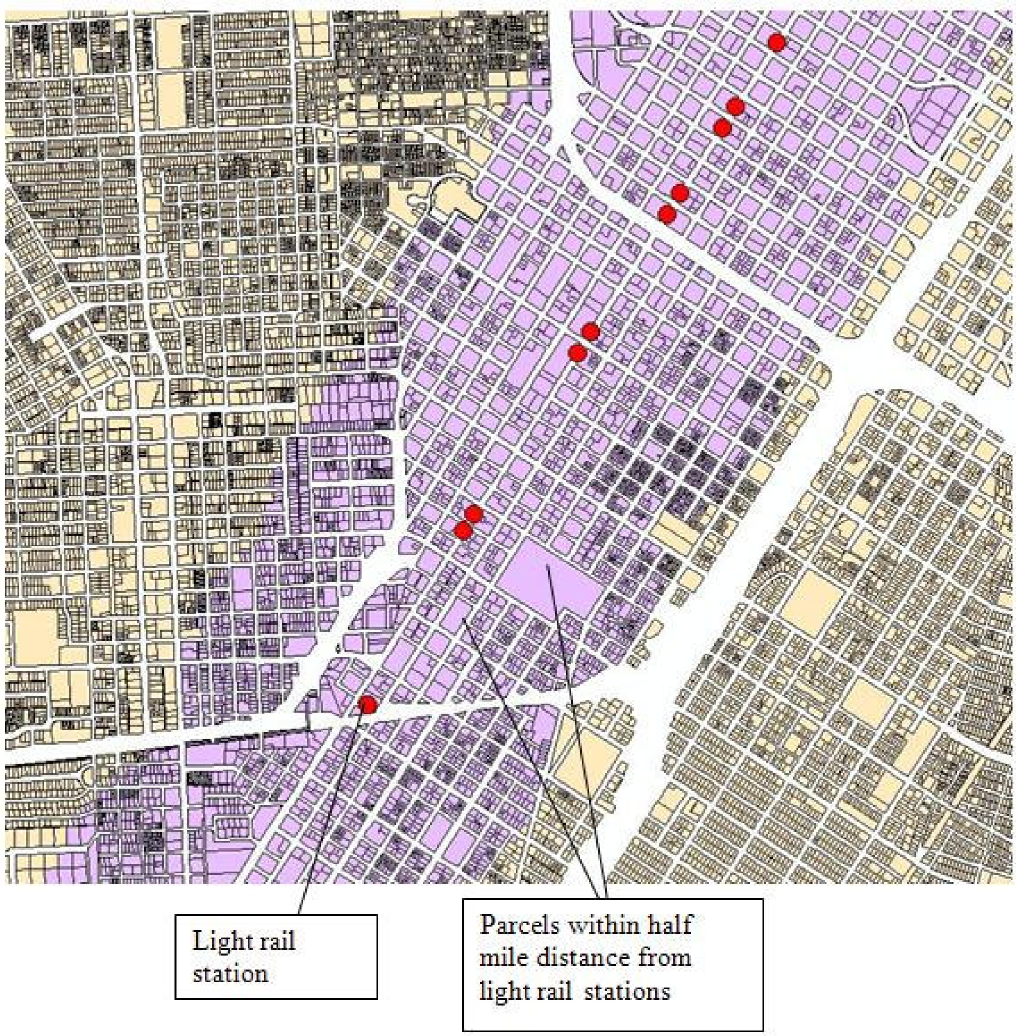


Figure 3.9: Data Collection Process of Treatment Group in GIS

Selection of Paired Control Group Parcels

Following steps were taken to select control group parcels.

Control group parcels: From population of all parcels which had zero improvement value, all parcels meeting LEED criteria were selected while defining the treatment group. So, rest of the population parcels formed control group.

GPS (X-Y) coordinates of all treatment group parcels: GPS coordinates of all 150-treatment group parcels were obtained using appropriate GPS tools. These coordinates were found out using complete address of each parcel.

Projecting one treatment parcel at a time: GPS coordinates of each treatment parcel were projected on GIS map, one parcel at a time. Figure 3.10 is a pictorial presentation of this procedure.

Figure 3.10: Projection of Treatment Sample Parcel on GIS Map

Locating control group parcels in vicinity of this treatment parcel projected: Using buffer function of GIS, all control group parcels which were located within half mile to one mile distance of the treatment parcel were selected. Figure 3.11 explains this procedure graphically.

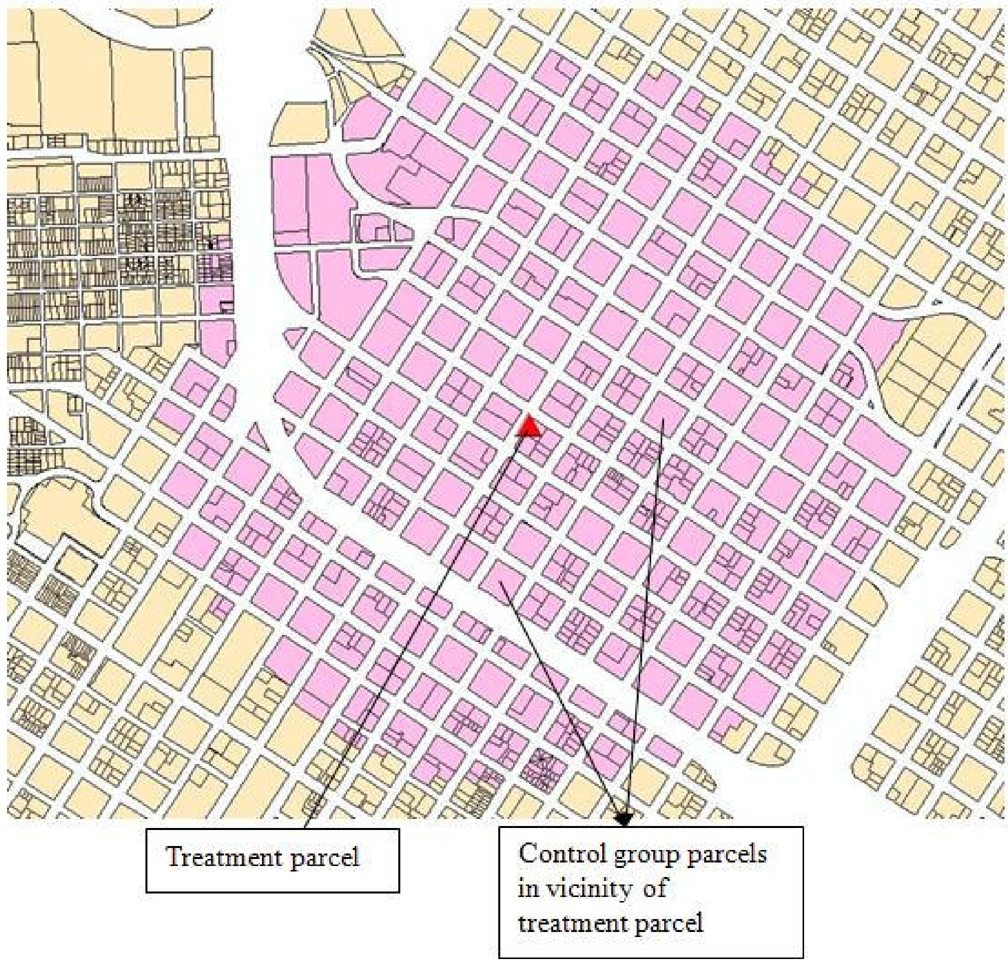


Figure 3.11: Locating Control Group Parcels for a Treatment Parcel Using GIS

Selecting paired control group parcel: One of these control group parcels was randomly selected to be paired up with treatment parcel. This way all 150 pairs of parcels were formed.

Area of Parcels

Area of all 150-paired parcels was obtained from Harris County Appraisal District public data. Using 13-digit parcel ID, information regarding land area was retrieved. Figure 3.12 illustrates this procedure.

Figure 3.12: Area of a Parcel as Obtained Using HCAD Website

Distance Measurement and Number Data

Using centroid of parcels as reference point distance to transit points was calculated. An excel matrix model was created using spherical law of cosines. With the help of this model, distances between a parcel and all transit points namely, bus stops and light rail stations were calculated. Using excel functions minimum bus stop and minimum light rail distances for a parcel were calculated and recorded. Distance data was calculated for all 300 parcels i.e. 150 treatment parcels and 150 corresponding control group parcels. With the help of matrix model number of bus stops and/or light rail stations that met LEED criteria for a parcel was also calculated. This number data was recorded only for 150 treatment parcels since they qualified for LEED credit. Figure 3.13 is a sample of excel model used. It was more suitable to select the centroid for distance measurements because extreme points on the parcels would not have justified comparisons within randomly selected parcels.

	A	B	C	D	E	F	G	H
1			PARCEL 1		PARCEL 2		PARCEL 3	
2			LATITUDE	LONGITUDE	LATITUDE	LONGITUDE	LATITUDE	LONGITUDE
3	LIGHT RAIL STATION LAT/LONG IN RADIANS		0.5188	-1.6647	0.5189	-1.6647	0.5188	-1.6648
4	LATITUDE	LONGITUDE	DISTANCE IN MILES					
5	0.5194	-1.6644	2.7833		2.5048		2.9785	
6	0.5194	-1.6644	2.4026		2.1248		2.5986	
7	0.5193	-1.6645	2.0247		1.7481		2.2216	
8	0.5192	-1.6645	1.7784		1.5031		1.9760	
9	0.5191	-1.6646	1.3819		1.1107		1.5807	
10	0.5191	-1.6647	0.9302		0.6735		1.1299	
11	0.5188	-1.6649	0.4035		0.6441		0.3455	
12	0.5188	-1.6648	0.3617		0.6155		0.2870	
13	0.5187	-1.6649	0.7882		1.0530		0.6514	
14	0.5186	-1.6650	1.1637		1.4385		0.9993	
15	0.5189	-1.6648	0.4446		0.2923		0.6349	
16	0.5185	-1.6651	1.6134		1.8907		1.4404	
17	0.5181	-1.6651	3.0561		3.3325		2.8589	
18	0.5179	-1.6651	3.8404		4.1110		3.6410	
19	0.5183	-1.6651	2.4554		2.7358		2.2659	
20	0.5184	-1.6651	1.9581		2.2378		1.7762	
21	0.5195	-1.6643	3.0824		2.8040		3.2777	
22	0.5179	-1.6651	4.0089		4.2784		3.8094	
23	0.5194	-1.6644	2.7118		2.4334		2.9071	
24	0.5185	-1.6651	1.5536		1.8307		1.3814	
25	0.5186	-1.6650	1.2219		1.4972		1.0558	
26	0.5190	-1.6647	0.8868		0.6331		1.0864	
27	0.5192	-1.6646	1.4409		1.1688		1.6395	
28	0.5192	-1.6645	1.8389		1.5633		2.0363	
29	0.5193	-1.6645	2.0866		1.8098		2.2834	
30	0.5193	-1.6644	2.2725		1.9951		2.4688	
31	MINIMUM DISTANCE (miles)		0.3617		0.2923		0.2870	
32	# MEETING LEED CRITERIA		3		1		2	

Figure 3.13: Excel Matrix

CHAPTER IV

RESULTS AND INTERPRETATION

Model 1

This model was used to determine if the unit value,($/SF), is significantly influenced by 1) Number of bus stops that met LEED criteria for a given parcel, 2) Number of light rail stations that met LEED criteria for a given parcel and 3) Area of parcel as expressed by the model:

Appraised Value/square foot of a parcel=$\beta_0 + \beta_1$ (Number of bus stops for a given parcel that met LEED criteria) + β_2 (Number of rail stations for a given parcel that met LEED criteria) + β_3 (Area of parcel) + ε

Plots

Scatter plot for unit value versus number of bus stops meeting LEED criteria indicated a positive relationship between the two variables. This relationship though positive was weak because even if data points seemed to line up but they did so weakly. Slope of this plot indicated that as the number of bus stops that met LEED criteria for a plot increased, unit value of the plot increased too. Figure 4.1 is pictorial presentation of the plot.

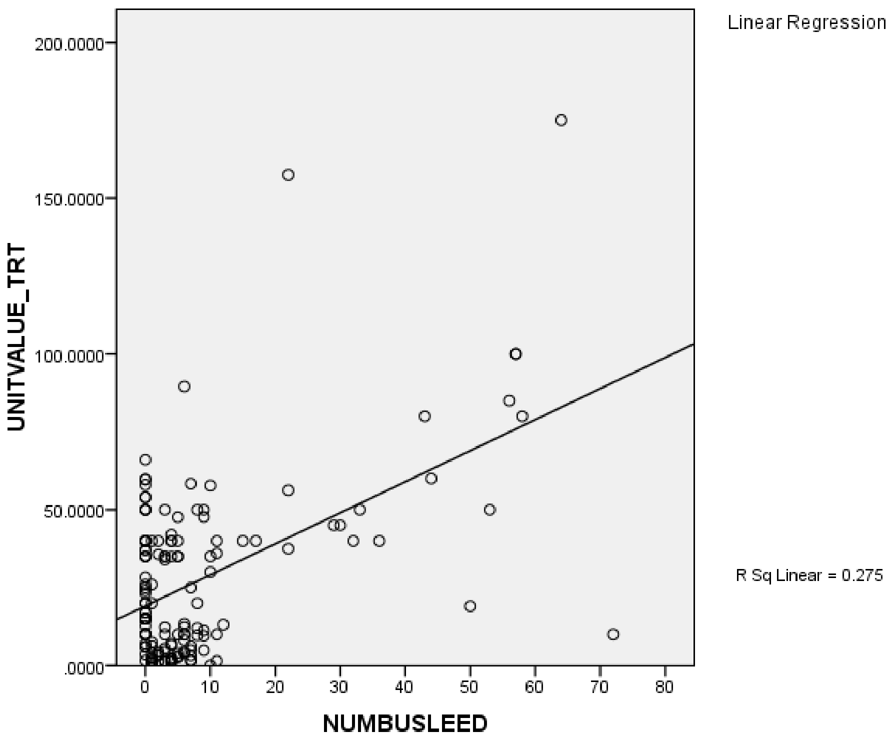


Figure 4.1: Scatterplot of Unit Value Vs. Number of Bus Stops Meeting LEED Criteria

Scatter plot for unit value versus number of light rail stations meeting LEED criteria was found to be much closer to the origin (0, 0) of the plot. Positive relationship though slightly weak was observed between the two variables. Slope of this plot like the previous one, indicated that as the number of light rail stations that met LEED criteria for a plot increased, unit value of the plot increased too. Figure 4.2 is pictorial presentation of the plot.

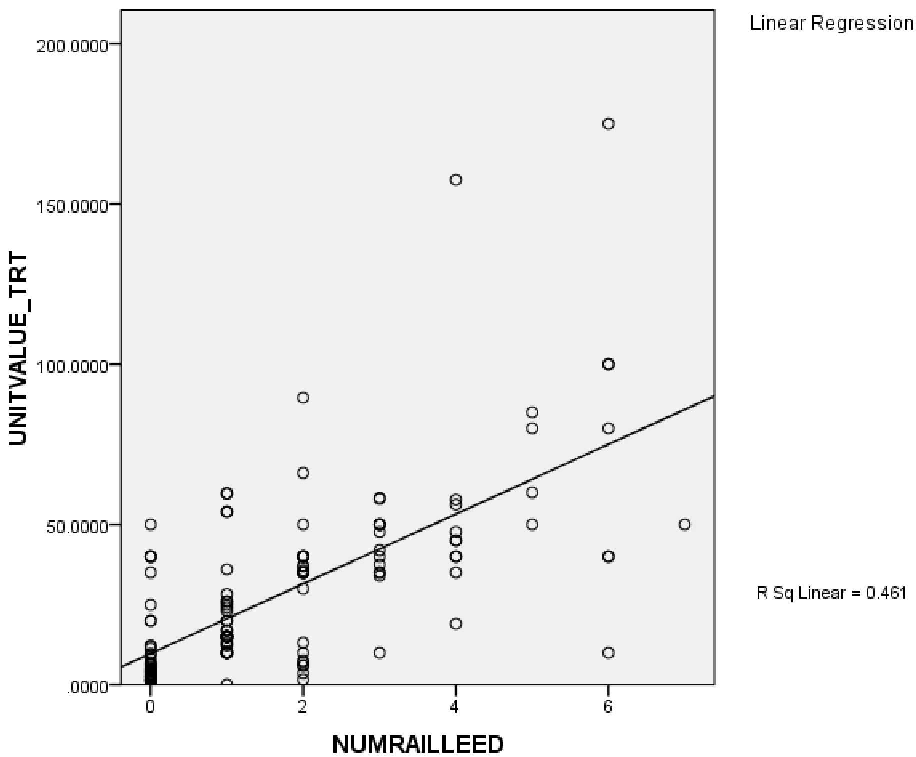


Figure 4.2: Scatterplot of Unit Value Vs. Number of Light Rail Stations Meeting LEED Criteria

Scatter plot for unit value versus area indicated a weak negative relationship. As the area of the parcel seemed to increase its associated unit value decreased. Figure 4.3 is pictorial presentation of the plot.

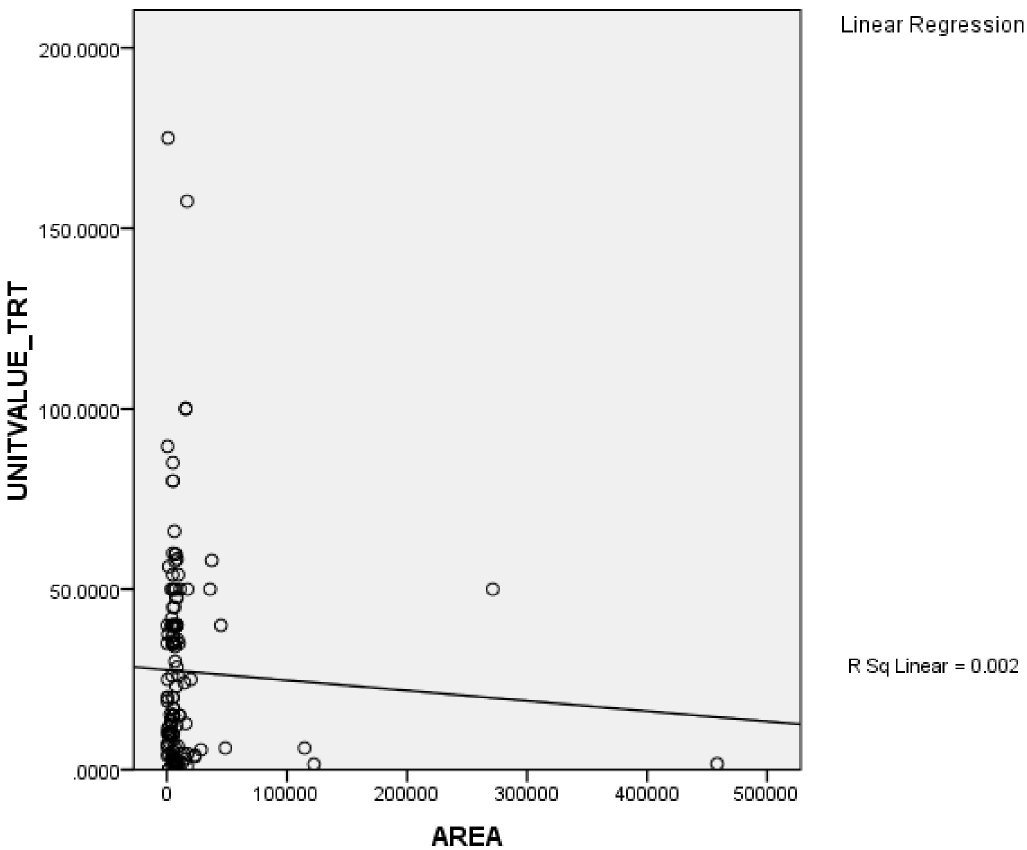


Figure 4.3: Scatterplot of Unit Value Vs. Area of Parcels

Descriptive Statistics

The dependent variable Unit value, ($/SF), had a mean value of about $27.25 per square foot and a median value of $ 17.00 per square foot. The lowest unit value was about $0.05 per square foot and the highest was $175.00 per square foot (see table 4.1). There were a few parcels that had a very high unit value per square foot in the treatment group dataset.

Table 4.1: Descriptive Statistics for Unit Value ($/SF) for Treatment Parcels

Descriptives

			Statistic	Std. Error
UNITVALUE_TRT	Mean		27.247172	2.2508732
	95% Confidence Interval for Mean	Lower Bound	22.799417	
		Upper Bound	31.694927	
	5% Trimmed Mean		24.100214	
	Median		17.000000	
	Variance		759.965	
	Std. Deviation		27.5674541	
	Minimum		.0504	
	Maximum		175.0000	
	Range		174.9496	
	Interquartile Range		33.7082	
	Skewness		2.178	.198
	Kurtosis		7.725	.394

The independent variable Area, (SF), had a mean of about 13536 square feet and a median of 5300 square feet. The lowest value was 41 square feet and the highest value was 458251 square feet (see table 4.2). Few of the parcels had a very high value of the land area associated with them whereas a large number of parcels were in the low land area category. Area considered for this set of results was 0.51% of the total undeveloped land area of City of Houston.

The appraised value, ($), had a mean value of about $311,638.00 and a median of $91,590. It ranged from $62 to $1, 356, 8900 (see table 4.2). Parcels with these lowest and highest appraised values met all the criteria to be in the population. These parcels had zero improvement value and qualified for LEED public transportation access credit.

Table 4.2: Descriptive Statistics for Area (SF) and Appraised Value ($) for Treatment Parcels

Descriptives

			Statistic	Std. Error
AREA	Mean		13535.81	3665.623
	95% Confidence Interval for Mean	Lower Bound	6292.49	
		Upper Bound	20779.13	
	5% Trimmed Mean		6773.19	
	Median		5300.00	
	Variance		2.016E9	
	Std. Deviation		44894.530	
	Minimum		41	
	Maximum		458251	
	Range		458210	
	Interquartile Range		4148	
	Skewness		8.074	.198
	Kurtosis		72.243	.394
valuetrt$	Mean		311637.6133	94508.37043
	95% Confidence Interval for Mean	Lower Bound	124887.8280	
		Upper Bound	498387.3987	
	5% Trimmed Mean		157334.5889	
	Median		91590.0000	
	Variance		1.340E12	
	Std. Deviation		1.15749E6	
	Minimum		62.00	
	Maximum		13568900.00	
	Range		13568838.00	
	Interquartile Range		265140.75	
	Skewness		10.342	.198
	Kurtosis		117.398	.394

Existence of Outliers in the Data and There Admissibility

Standardized residuals and centered leverage values indicated existence of problem points in the data. Table 4.3 presents descriptive statistics for the standardized residuals, cook's distances and centered leverage values. Minimum and maximum values for standardized residuals and leverage values were more than acceptable ranges. Figure 4.4 is a time series plot for leverage values. This plot indicated presence of outliers.

Table 4.3: Descriptive Statistics for the Standardized Residuals, Cook's Distances and Centered Leverage Values

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Standardized Residual	150	-3.31896	5.12606	.0000000	.98988170
Cook's Distance	150	.00000	.78066	.0187551	.09196930
Centered Leverage Value	150	.00056	.65916	.0200000	.05888432
Valid N (listwise)	150				

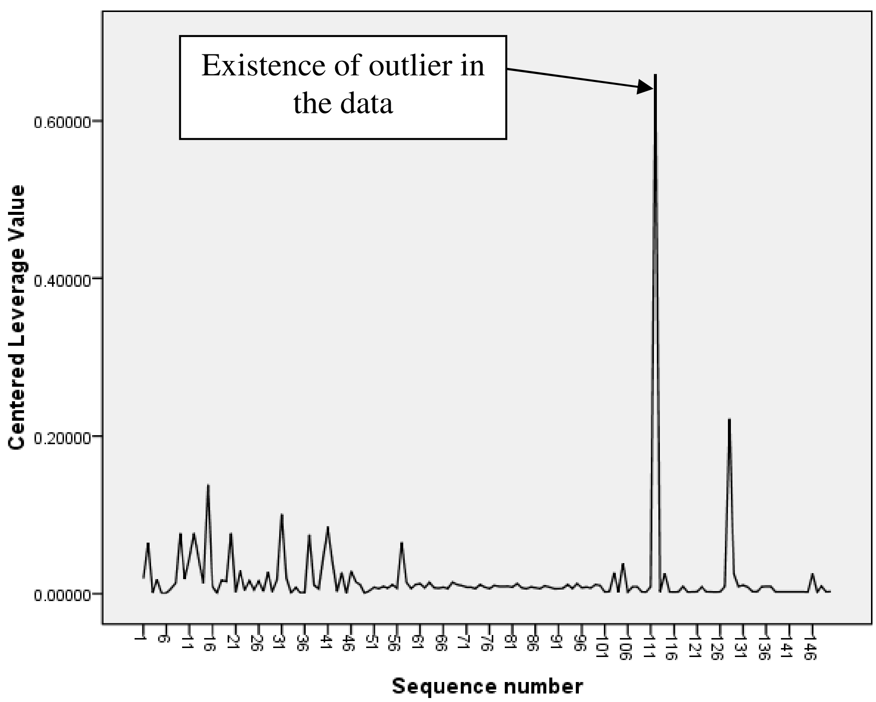


Figure 4.4: Time Series Plot for Centered Leverage Values

Box plot indicated (see figure 4.5) that the dataset had 2 massive outliers and 2 moderate outliers. All these four observations were used in the analysis since they were parcels which met population criteria of zero improvement value. Also, each of these parcels met LEED criteria of public transportation access. Admissibility of these parcels was further verified by checking whether or not they qualified for tax exemption and it was found that they were not exempted lands. This could be gathered from the table 4.4. Hence, they were used in the analysis.

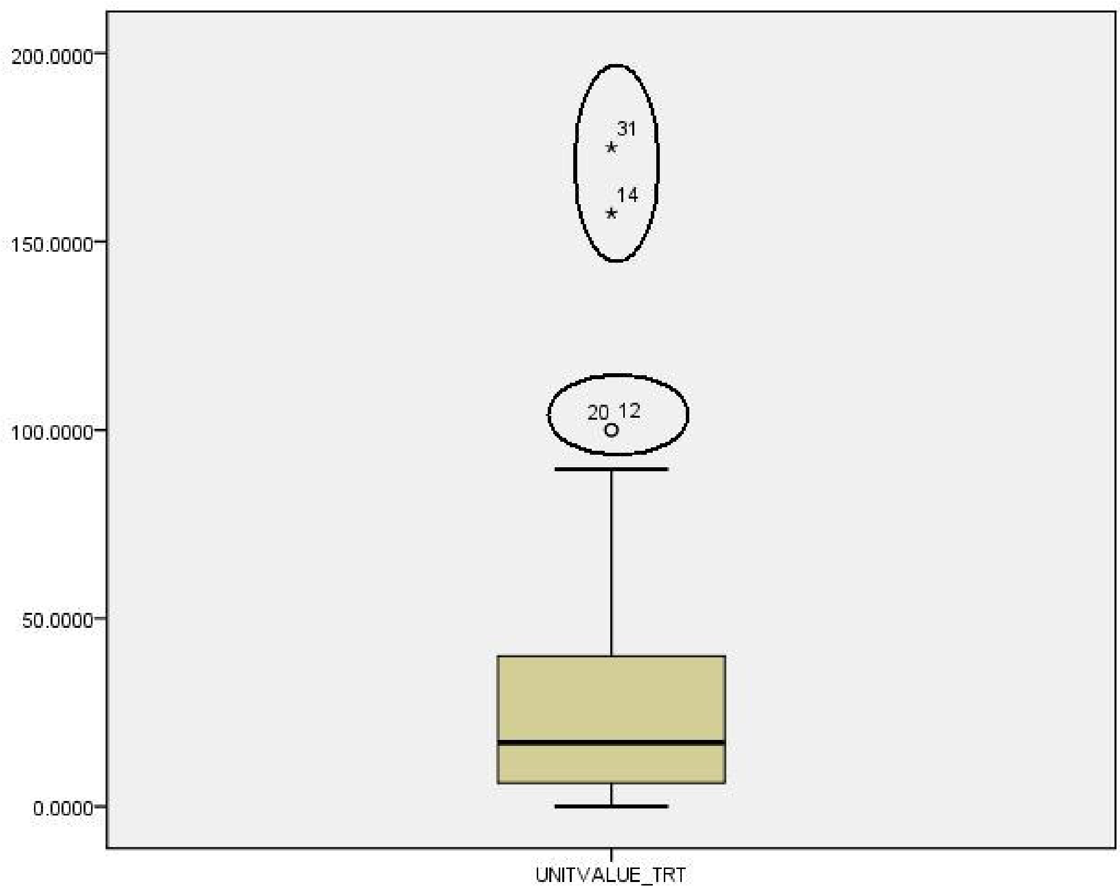


Figure 4.5: Box Plot for Unit Value of Treatment Parcels

Table 4.4: Data for Outliers

OBS	MINBUS TRTDIST	MINRAIL TRTDIST	NUMBUS LEED	NUMRAIL LEED	AREA	STATE CATEGORY CODE
12	0.03864	0.04962	57	6	15625	C2 -- Real, Vacant Commercial
14	0.02276	0.29809	22	4	16719	C2 -- Real, Vacant Commercial
20	0.03864	0.04962	57	6	15625	C2 -- Real, Vacant Commercial
29	0.08681	0.45704	6	2	450	C1 -- Real, Vacant Lots/Tracts (In City)
31	0.02431	0.09346	64	6	800	C2 -- Real, Vacant Commercial

Check for Collinearity between Independent Variables

To check the presence of multi collinearity between independent variables, collinearity statistics were used. Matrix plot of independent variables (see figure 4.6) indicated that no multi-collinearity existed between these variables. As could be seen from the table 4.5, variance inflation factor (VIF) for independent variables was found to be less than 10. This reinforced the fact that no multi-collinearity existed between the independent variables.

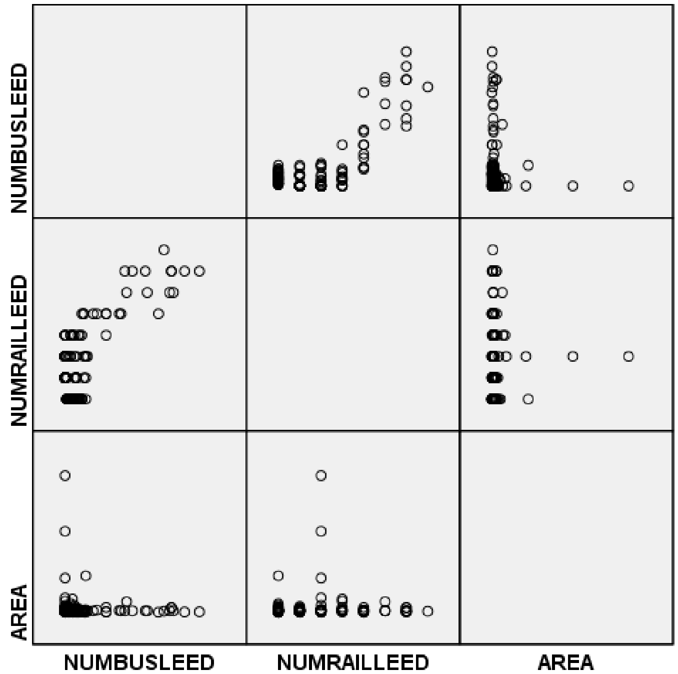


Figure 4.6: Matrix Plot of Independent Variables

Table 4.5: Variance Inflation Factors for Independent Variables

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	10.354	2.340		4.425	.000		
	NUMBUSLEED	.055	.174	.029	.315	.753	.436	2.292
	NUMRAILLEED	10.553	1.463	.659	7.215	.000	.439	2.280
	AREA	-3.754E-5	.000	-.061	-1.000	.319	.980	1.021

a. Dependent Variable: UNITVALUE_TRT

Correlation between Variables

Spearman's correlation (see table 4.6) was used since the normality assumption was not met by the residuals. It was found that out of all the independent variables considered for this model only number of light rail stations was significantly correlated to the unit value. Positive correlation existed between unit value and number of light rail stations meeting LEED criteria. This meant that unit value of parcel went up as the number of light rail stations meeting LEED criteria for a given parcel increased.

Table 4.6: Spearman's Correlation Results

Correlations

			UNITVALUE_TRT	NUMBUSLEED	NUMRAILLEED	AREA
Spearman's rho	UNITVALUE_TRT	Correlation Coefficient	1.000	.139	.717**	.040
		Sig. (2-tailed)	.	.091	.000	.631
		N	150	150	150	150
	NUMBUSLEED	Correlation Coefficient	.139	1.000	.218**	-.228**
		Sig. (2-tailed)	.091	.	.007	.005
		N	150	150	150	150
	NUMRAILLEED	Correlation Coefficient	.717**	.218**	1.000	-.002
		Sig. (2-tailed)	.000	.007	.	.977
		N	150	150	150	150
	AREA	Correlation Coefficient	.040	-.228**	-.002	1.000
		Sig. (2-tailed)	.631	.005	.977	.
		N	150	150	150	150

**. Correlation is significant at the 0.01 level (2-tailed).

Number of bus stops meeting LEED criteria was found significantly correlated to both number of light rail stations and area. Positive correlation existed between number of bus stops and number of light rail stations. It meant that number of bus stops increased as the number of light rails stations increased. However, a negative correlation existed between number of bus stops and area of parcel. Number of bus stops went down as the plot size increased. Like mentioned earlier, parcels with large areas are located more towards the city boundaries discounting the patterns of urbanization. This may be the reason of inverse relationship between the number of bus stops and area.

Number of light rail stations meeting LEED criteria was not significantly correlated to the area. This may be because the light rail network in the City of Houston is concentrated more towards the center of the city i.e. down town area. Also, like mentioned earlier vacant parcels located inside loop 610 are small in size. These two factors may be the cause of no correlation between the two variables.

Multiple Regression

Original Model

Multiple regression analysis for the model with original dependent variable presented adjusted R square value of 0.455 (see table 4.7). Also, p value of 0.000 in the Anova table (see table 4.8) proved that the model was significant. Of all the three independent variables considered only number of light rail stations meeting LEED criteria emerged as significant predictor of the unit value (see table 4.9). Before proceeding for the interpretation, it was essential to check if formal assumptions for multiple linear regression were satisfied.

Table 4.7: Adjusted R- Square for the Model 1

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.682[a]	.466	.455	20.3577152

a. Predictors: (Constant), AREA, NUMRAILLEED, NUMBUSLEED

b. Dependent Variable: UNITVALUE_TRT

Table 4.8: Anova Significance Value for the Model 1

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	52726.975	3	17575.658	42.409	.000[a]
	Residual	60507.739	146	414.437		
	Total	113234.714	149			

a. Predictors: (Constant), AREA, NUMRAILLEED, NUMBUSLEED

b. Dependent Variable: UNITVALUE_TRT

Table 4.9: Population Parameters Significance Values

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	10.354	2.340		4.425	.000	5.730	14.978		
	NUMBUSLEED	.055	.174	.029	.315	.753	-.289	.399	.436	2.292
	NUMRAILLEED	10.553	1.463	.659	7.215	.000	7.663	13.444	.439	2.280
	AREA	-3.754E-5	.000	-.061	-1.000	.319	.000	.000	.980	1.021

a. Dependent Variable: UNITVALUE_TRT

Diagnostics

Normality of Residuals

Since the sample size for this model was more than 50; Kolmogorov Smirnov significance value was used for testing normality of residuals. $p = 0.000 < 0.05$(Alpha level) for Kolmogorov- Smirnov test of normality proved that residuals were not normal (see table 4.10). Hence, normality test was failed by residuals. Also, histogram of standardized residuals presented non-normal distribution of residuals (see figure 4.7).

Table 4.10: Kolmogorov Smirnov Significance Value for Model 1

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Standardized Residual	.173	150	.000	.831	150	.000

a. Lilliefors Significance Correction

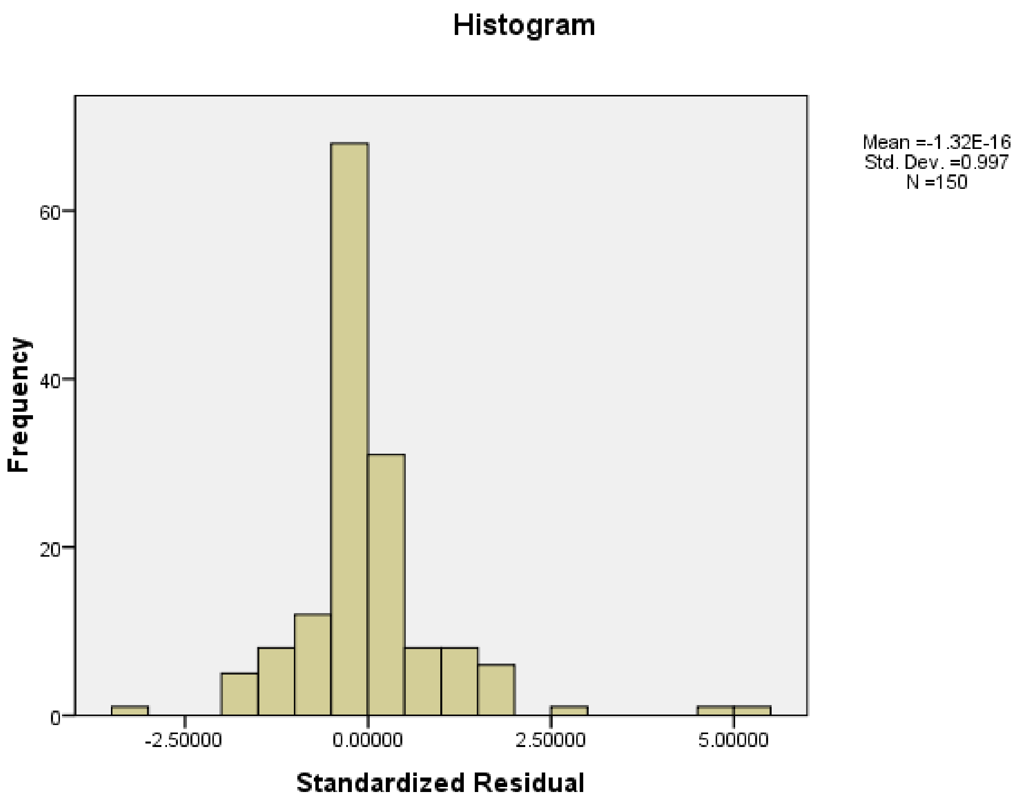


Figure 4.7: Histogram for Standardized Residuals

Constant Variance of Residuals

Since normality assumption was not met by residuals, Koenker significance value was used to test the constant variance of residuals. p= 0.000 < 0.05 (Alpha level) for Koenker test for homoscedasticity proved that constant variance assumption was not satisfied (see figure 4.8).Hence, homoscedasticity test was failed by residuals.

```
Run MATRIX procedure:

Regression SS
 243.8669

Residual SS
 1260.587

Total SS
 1504.453

R-squared
    .1621

Sample size (N)
  150

Number of predictors (P)
    3

Breusch-Pagan test for Heteroscedasticity (CHI-SQUARE df=P)
  121.933

Significance level of Chi-square df=P (H0:homoscedasticity)
    .0000

Koenker test for Heteroscedasticity (CHI-SQUARE df=P)
   24.315

Significance level of Chi-square df=P(H0:homoscedasticity)
    .0000

------ END MATRIX -----
```

Figure 4.8: Koenker Test for Homoscedasticity

Transformation of Dependent Variable

Since, formal assumptions to carry out regression were not met, dependent variable i.e. unit value was transformed. Box-Cox transformation was used to find the appropriate transformation.

Box-Cox suggested two possible transformations for the dependent variable (see figure 4.9). For the analysis purposes, following transformation was used.

Transformed Unit Value = (Original Unit Value)$^{0.3}$

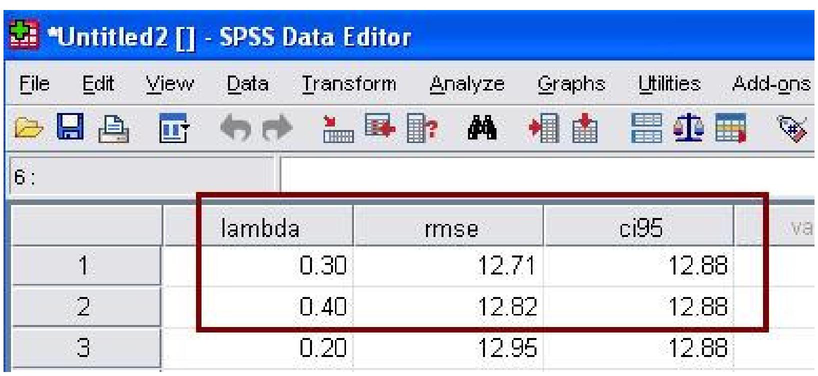


Figure 4.9: Transformation Suggested by Box Cox Procedure

Variable Selection

As could be seen from the table 4.11, all the independent variables entered into the model remained in the model. None of the variables was removed by backward elimination method. This was interesting, because both number of bus stops and area emerged as non –significantly correlated to the unit value earlier. But post transformation of the dependent variable these two independent variables became significant.

Table 4.11: Backward Elimination Method

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	AREA, NUMRAILLEED, NUMBUSLEED[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: Transformed Unit Value

Multiple Regression Analysis with Transformed Dependent Variable and Interpretation

Following model was considered after the transformation:

Transformed Unit Value = $\beta_0 + \beta_1$ (Number of bus stops) + β_2 (Number of light rail stations) + β_3 (Area) + ε

Increase or decrease in the transformed dependent variable also resulted in increase or decrease in the original dependent variable respectively. Only the magnitude of this increase or decrease was different for the transformed and original dependent variable. Table 4.12 explains this phenomenon in detail.

Table 4.12: Transformed and Original Dependent Variable for Model 1

	Unit Value	*Unit Value*	*Unit Value*
Original Dependent Variable (y)	3	10	40
Transformed Dependent Variable [yt = y ^ 0.3]	1.390	1.995	3.024
Untransformed Dependent Variable = yt^ (1/0.3)	3	10	40

P-value for this model was 0.000 < 0.05 (see table 4.13). Anova table p value tested the hypothesis that there was no linear relationship between dependent and independent variables. From the p value obtained from the analysis it could be said that this hypothesis was rejected. Hence, the statistical model was significant and that linear relationship existed between dependent and independent variables.

Speaking in terms of the research variables, transformed unit value of parcels was found linearly related to the area, number of bus stops and number of rail stations. Since, this relationship existed; the multiple regression correlation value was also significant.

Adjusted R- square for this model was 0.493(see table 4.14). That is 49.3% variability in transformed unit value of parcels could be explained by the independent variables. Even though all independent variables were found to be significant predictors, they were not powerful. Because only 49.3% variability in the transformed unit value of parcels could be explained by these independent variables, whereas 50.7% of the variability was explained by some other relevant factors not considered in this research study.

Table 4.13: Anova Significance Value for the Model

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	52.203	3	17.401	49.252	.000[a]
	Residual	51.582	146	.353		
	Total	103.785	149			

a. Predictors: (Constant), AREA, NUMRAILLEED, NUMBUSLEED

b. Dependent Variable: Transformed Unit Value

Table 4.14: Adjusted R- Square for the Model

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.709[a]	.503	.493	.59439

a. Predictors: (Constant), AREA, NUMRAILLEED, NUMBUSLEED

b. Dependent Variable: Transformed Unit Value

$\beta_1 = -0.015$, partial slope for number of bus stops was -0.015 (see table 4.15). This meant that as the number of bus stops meeting LEED criteria increased for a given parcel, transformed unit value of that parcel went down. This trend was interesting to note because prior to the transformation of the dependent variable, parameter estimate for partial slope for number of bus stops was 0.055. It gave completely opposite implication on the unit value of a parcel.

$\beta_2 = 0.426$, partial slope for number of rail stations was 0.426 (see table 4.15).

This meant that as the number of rail stations meeting LEED criteria for a given parcel increased, transformed unit value of that parcel increased.

β_3 = -0.000002522, partial slope for area was -0.000002522 (see table 4.15). This meant that as the area of parcel increased, its transformed unit value went down.

Table 4.15: Population Parameters for Model 1

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.873	.068		27.422	.000
	NUMBUSLEED	-.015	.005	-.265	-3.004	.003
	NUMRAILLEED	.426	.043	.879	9.980	.000
	AREA	-2.522E-6	.000	-.136	-2.301	.023

a. Dependent Variable: Transformed Unit Value

Parameter estimates (see table 4.15) showed that all three independent variables; number of bus stops, number of rail stations and area were significant predictors of transformed unit value of parcel. Number of rail stations meeting LEED criteria for a given parcel had the greatest prediction of the transformed unit value as compared to other independent variables of the model.

Following was the predictive equation obtained for transformed unit value. This model used the best estimates of the population parameters.

Predicted Transformed Unit value= 1.873 -0.015 (Num Bus stops) + 0.426 (Num Rail Stations) – 0.000002522 (area)

Predicted Un-Transformed Unit value= [1.873 -0.015 (Num Bus stops) + 0.426 (Num Rail Stations) – 0.000002522 (area)] $^{(1/0.3)}$

Following results were found when spearman's correlation with original dependent variable and multiple regression with transformed dependent variable were compared. Number of bus stops and area were not significantly correlated to the unit value when spearman's test was run using the original dependent variable. Whereas multiple regression analysis when transformed dependent variable was used, showed that both number of bus stops and area were significant predictors of the transformed unit value. This change may be because of the transformation done on the dependent variable.

Model 2

This model was used to determine if the unit value, ($/SF), is significantly influenced by 1) Distance to the nearest bus stop, 2) Distance to the nearest light rail station and 3) Area of parcel as expressed by the model:

Appraised Value/square foot of a parcel=β_0 + β_1 (Minimum distance of bus stop) + β_2 (Minimum distance of rail station) + β_3 (Area of parcel) + ε

Plots

Scatter plot for unit value versus minimum bus distance showed that negative relationship existed between the two variables. The plot indicated a weak negative relationship between the two variables. From the slope it was found that the unit value of the parcel went down as the distance to the nearest public transit point (in this case bus stop) increased. Figure 4.10 is a scatter plot between Unit value and minimum bus distance.

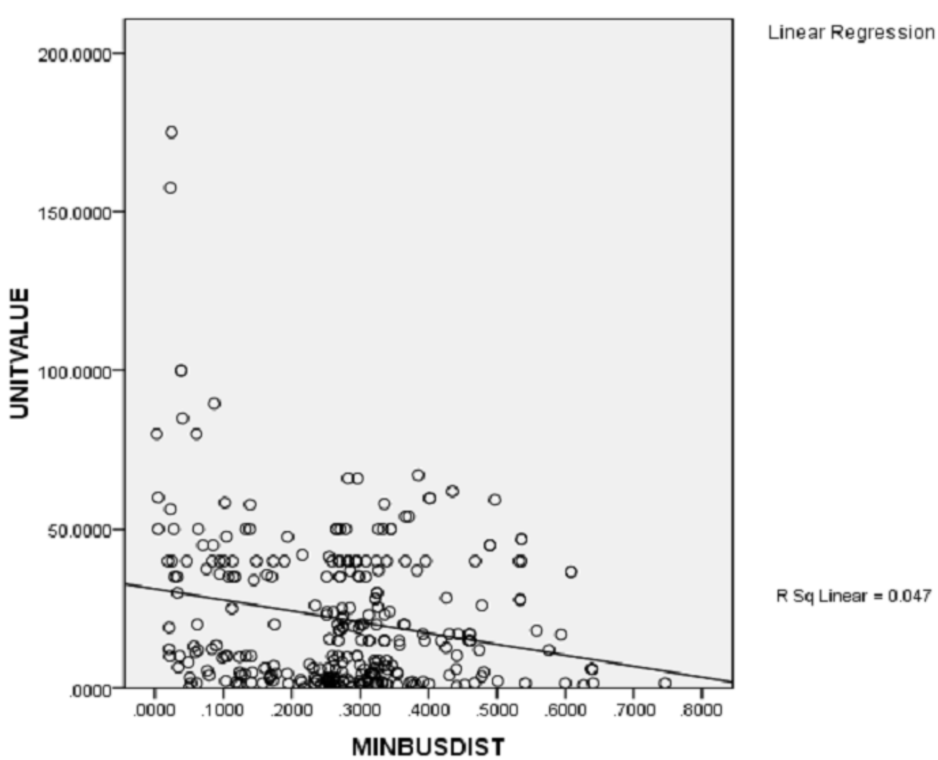


Figure 4.10: Scatterplot of Unit Value Vs Minimum Bus Distance

Scatter plot for unit value versus minimum light rail station distance indicated same relationship pattern as for the minimum bus stop distance. The plot indicated a weak negative relationship between the two variables. From the slope it was found that the unit value of the parcel went down as the distance to the nearest public transit point (in this case light rail station) increased. Figure 4.11 is a scatter plot between Unit value and minimum light rail distance.

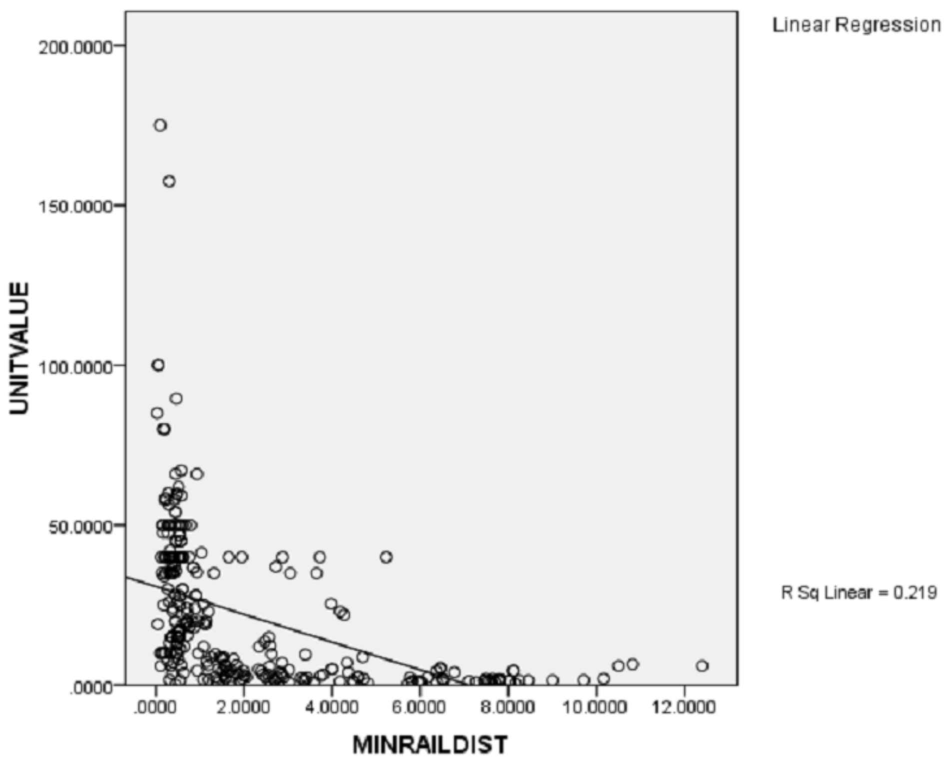


Figure 4.11: Scatterplot of Unit Value Vs Minimum Light Rail Distance

Scatter plot for unit value versus area indicated non-significant relationship between the two variables. With this plot it could be said that the unit value was not affected by the plot size. Figure 4.12 is a scatter plot between Unit value and area.

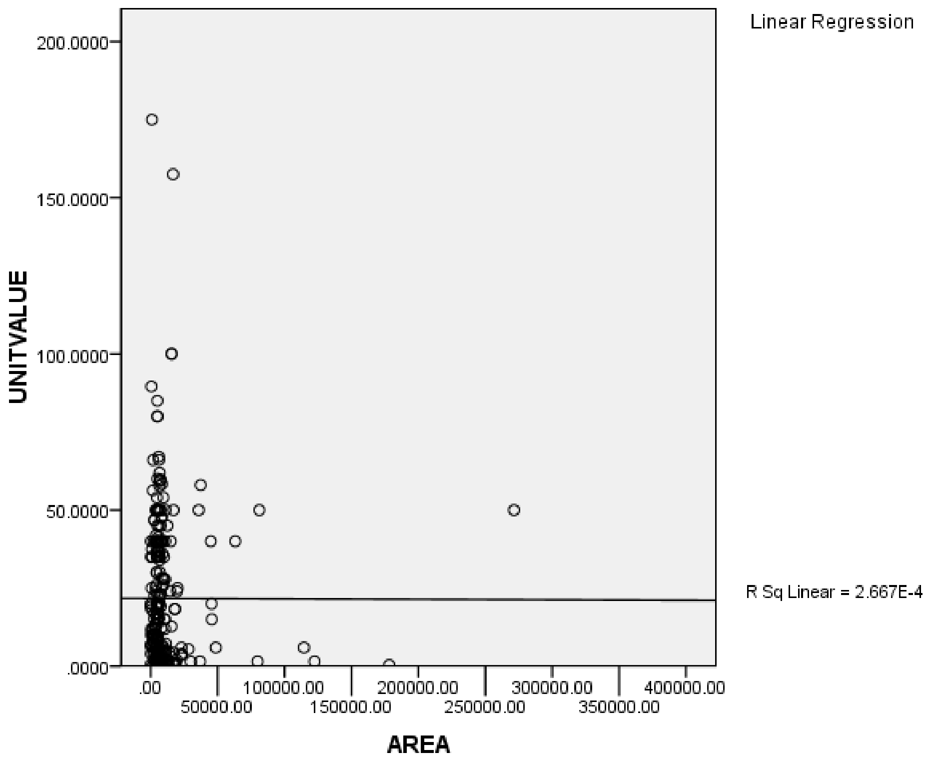


Figure 4.12: Scatterplot of Unit Value Vs Area

Descriptive Statistics

The dependent variable unit value, ($/SF), had a mean of about $22 per square foot and a median of $15 per square foot. The lowest unit value was $0.05 per square foot and the highest value was $ 175 per square foot (see table 4.16). There were few parcels that had a very high unit value associated with them. Parcels with lowest and highest unit values were eligible to be in the population of interest. They had zero improvement value and were within the population boundary.

Table 4.16: Descriptive Statistics for Unit Value

Descriptives

			Statistic	Std. Error
UNITVALUE	Mean		21.666561	1.3589051
	95% Confidence Interval for Mean	Lower Bound	18.992331	
		Upper Bound	24.340791	
	5% Trimmed Mean		19.193199	
	Median		15.000000	
	Variance		553.987	
	Std. Deviation		23.5369267	
	Minimum		.0504	
	Maximum		175.0000	
	Range		174.9496	
	Interquartile Range		33.6064	
	Skewness		2.236	.141
	Kurtosis		9.109	.281

The independent variable area, (SF), had a mean of about 26,733 square feet and a median of about 5,613 square feet. The lowest value was 41 square feet and the highest value was 4,435,829 square feet (see table 4.17). Total vacant land area covered in this study was 8,019,999 square feet, 2.02 % of the total undeveloped land area of City of Houston (see table 4.18).

Table 4.17: Descriptive Statistics for Area and Appraised Value

Descriptives			Statistic	Std. Error
AREA	Mean		26733.3300	14877.60243
	95% Confidence Interval for Mean	Lower Bound	-2544.7452	
		Upper Bound	56011.4052	
	5% Trimmed Mean		7232.7222	
	Median		5612.5000	
	Variance		6.640E10	
	Std. Deviation		2.57688E5	
	Minimum		41.00	
	Maximum		4435829.00	
	Range		4435788.00	
	Interquartile Range		3972.50	
	Skewness		16.885	.141
	Kurtosis		289.461	.281
VALUE_$	Mean		480507.7467	2.53142E5
	95% Confidence Interval for Mean	Lower Bound	-17656.9233	
		Upper Bound	978672.4166	
	5% Trimmed Mean		125650.9852	
	Median		75000.0000	
	Variance		1.922E13	
	Std. Deviation		4.38454E6	
	Minimum		62.00	
	Maximum		74668035.00	
	Range		74667973.00	
	Interquartile Range		203787.50	
	Skewness		16.402	.141
	Kurtosis		276.929	.281

Table 4.18: Descriptive Statistics with Total Value of Area and Appraised Value

Descriptive Statistics	N	Minimum	Maximum	Sum	Mean	Std. Deviation
AREA	300	41.00	4435829.00	8019999.00	26733.3300	2.57688E5
VALUE_$	300	62.00	74668035.00	1.44E8	480507.7467	4.38454E6
Valid N (listwise)	300					

Value, ($), of the land had a mean of about $480,508 and a median of $75,000. The lowest value was $62 and the highest was $74,668,035 (see table 4.17). Parcels with these lowest and highest appraised values were eligible to be in the population of interest. They had zero improvement value.

Existence of Outliers in the Data and There Admissibility

Table 4.19: Indicators of Problem Points in the Dataset

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Standardized Residual	300	-1.75558	6.71676	.0000000	.99497063
Cook's Distance	300	.00000	4.48982	.0178696	.25938035
Centered Leverage Value	300	.00003	.97928	.0100000	.05670961
Valid N (listwise)	300				

Descriptive statistics (see table 4.19) showed that residuals, cook's distances and leverage values indicated existence of problem points in the data. Figure 4.13 is a plot between standardized residuals and one of the independent variables. This plot showed presence of possible problem points in the dataset.

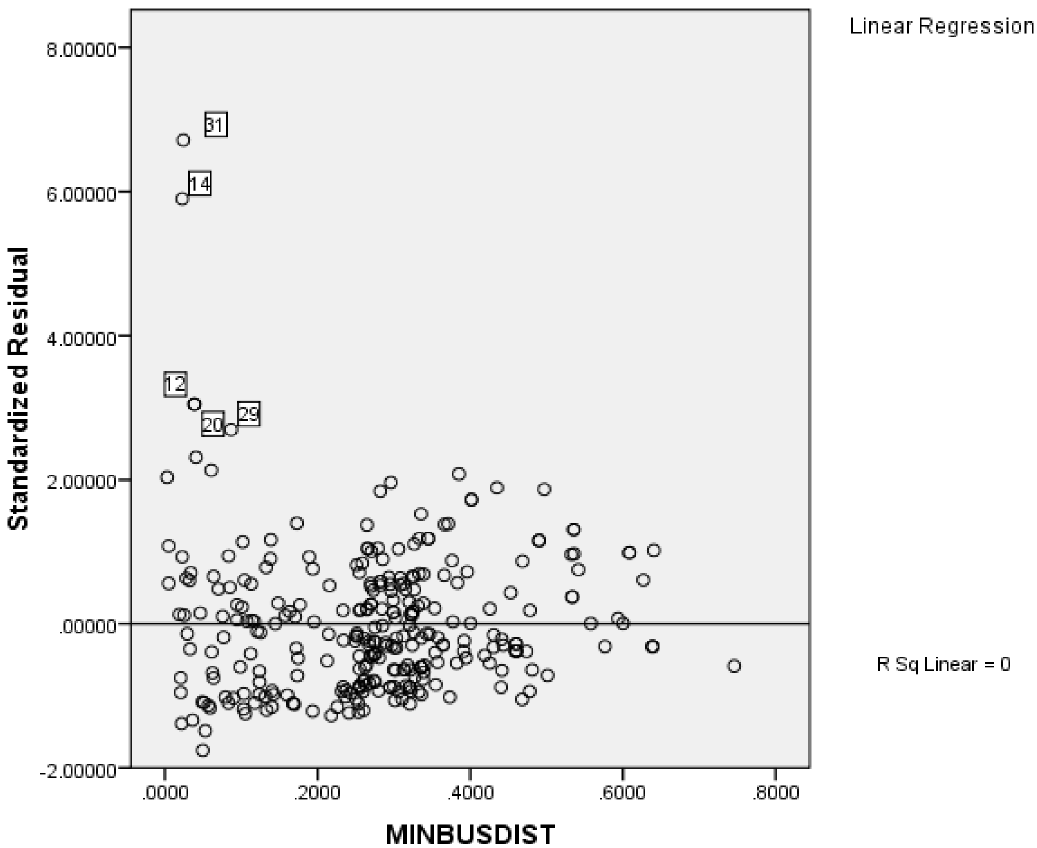


Figure 4.13: Plot Between Standardized Residuals and Minimum Bus Distance

Box plot (see figure 4.14) was used to determine what observations were outliers in the data. It was found that the data had 2 massive outliers and 3 moderate outliers. All these five observations were used in the analysis since they all met conditions to be in the population. These parcels had zero improvement value and also they were not tax exempted land. Hence, the admissibility of these parcels in the data was justified.

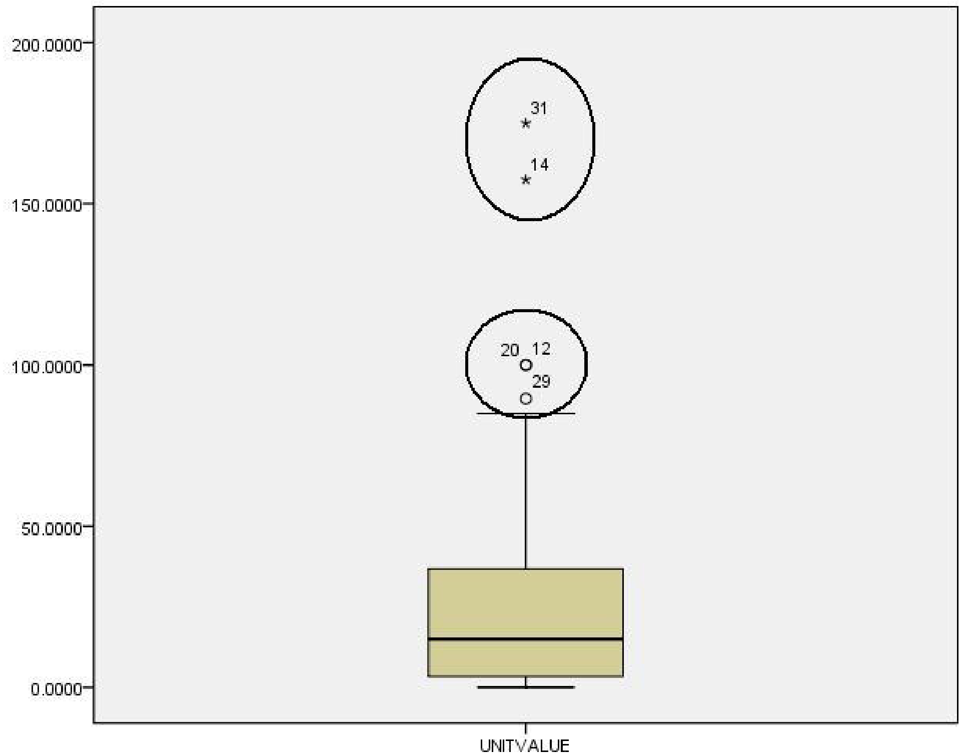


Figure 4.14: Box Plot

Check for Collinearity Between Independent Variables

To check the multi collinearity between independent variables, collinearity statistics were used. Matrix plot (see figure 4.15) of all independent variables showed that no multi-collinearity existed between these variables. Variance inflation factors for all three independent variables were below 10 (see table 4.20). Hence, there was no multi collinearity between the independent variables.

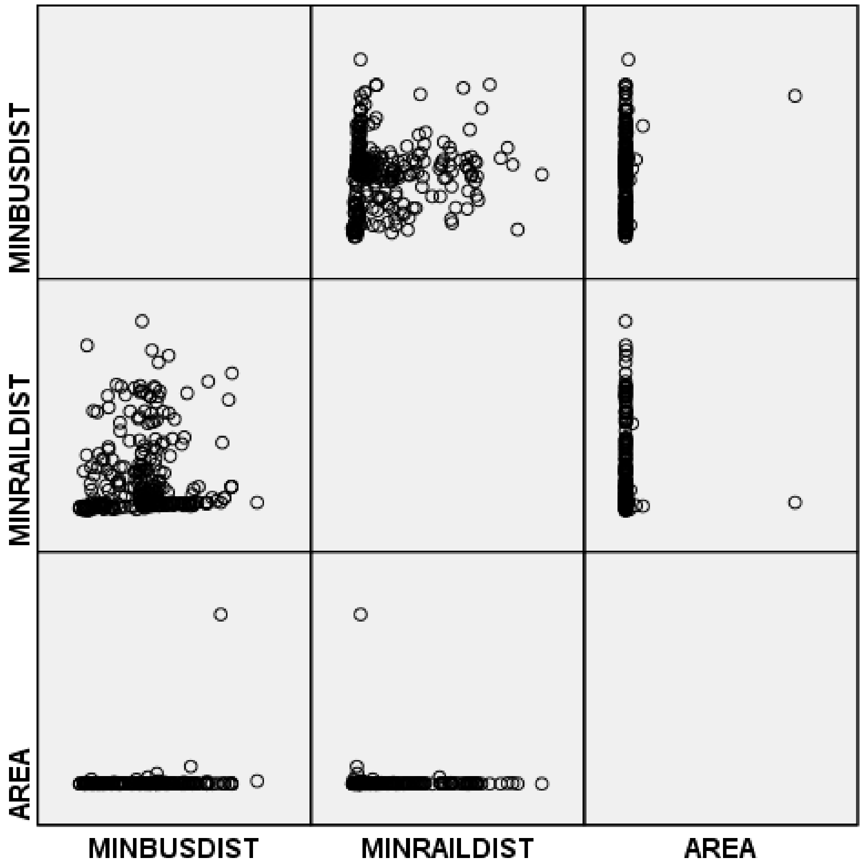


Figure 4.15: Matrix Plot for Independent Variables

Table 4.20: Variance Inflation Factors

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	39.297	2.660		14.775	.000		
	MINBUSDIST	-31.488	8.147	-.196	-3.865	.000	.978	1.022
	MINRAILDIST	-4.267	.465	-.460	-9.177	.000	.996	1.004
	AREA	-6.619E-7	.000	-.007	-.143	.886	.979	1.022

a. Dependent Variable: UNITVALUE

Correlation between Variables

Since the normality assumption for residuals was not satisfied, spearman's correlation (see table 4.21) was used. It was found that of all the independent variables considered for this model only minimum light rail station distance and area were significantly correlated with the unit value. Unit Value was found to be negatively correlated with both minimum light rail station distance and area. This meant that unit value of a property went up as its distance to the nearest light rail station decreased. This showed that proximity to the light rail station led to increase in the unit value of the property. Also, unit value went down as the area increased. This pattern may be because large sized vacant parcels are located towards the city boundary.

Minimum bus stop distance was found to be significantly correlated with the minimum light rail station distance and area. Minimum distance to the bus stop increased, as distance to the nearest light rail station increased. Also, minimum distance to the bus stop increased as the plot size increased. This is reasonable since the distances in this research study were calculated using centroid of plot.

Minimum light rail station distance was significantly correlated with area. This phenomenon was interesting to note because the number of light rail stations which met LEED criteria was not correlated with area in the previous model. Minimum distance to the light rail station increased, as the plot size increased. This is reasonable since the distances for this research study were calculated from the centroid of the plot.

Table 4.21: Spearman's Correlation

Correlations

			UNITVALUE	MINBUSDIST	MINRAILDIST	AREA
Spearman's rho	UNITVALUE	Correlation Coefficient	1.000	-.101	-.697**	-.124*
		Sig. (2-tailed)	.	.081	.000	.031
		N	300	300	300	300
	MINBUSDIST	Correlation Coefficient	-.101	1.000	.133*	.216**
		Sig. (2-tailed)	.081	.	.022	.000
		N	300	300	300	300
	MINRAILDIST	Correlation Coefficient	-.697**	.133*	1.000	.138*
		Sig. (2-tailed)	.000	.022	.	.017
		N	300	300	300	300
	AREA	Correlation Coefficient	-.124*	.216**	.138*	1.000
		Sig. (2-tailed)	.031	.000	.017	.
		N	300	300	300	300

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Multiple Regression

Original Model

Multiple regression analysis for the model with original dependent variable presented adjusted R square value of 0.25 (see table 4.22). Also, p value of 0.000 in the Anova table (see table 4.23) proved that the model was significant. Of all the three independent variables considered only minimum bus distance and minimum light rail station distance emerged as significant predictors of the unit value (see table 4.24). Before proceeding for the interpretation, it was essential to check if formal assumptions for multiple linear regression were satisfied.

Table 4.22: Adjusted R- Square for the Original Model

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.508[a]	.258	.250	20.3770491

a. Predictors: (Constant), AREA, MINRAILDIST, MINBUSDIST

b. Dependent Variable: UNITVALUE

Table 4.23: Anova Significance Value for the Original Model

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	42735.747	3	14245.249	34.307	.000[a]
	Residual	122906.342	296	415.224		
	Total	165642.089	299			

a. Predictors: (Constant), AREA, MINRAILDIST, MINBUSDIST

b. Dependent Variable: UNITVALUE

Table 4.24: Population Parameters for the Original Model

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	39.297	2.660		14.775	.000	34.063	44.532
	MINBUSDIST	-31.488	8.147	-.196	-3.865	.000	-47.522	-15.455
	MINRAILDIST	-4.267	.465	-.460	-9.177	.000	-5.182	-3.352
	AREA	-6.619E-7	.000	-.007	-.143	.886	.000	.000

a. Dependent Variable: UNITVALUE

Diagnostics

Normality of Residuals

Histogram for the standardized residuals indicated non- normal distribution (see figure 4.16). Also, Kolmogorov-Smirnov test of normality with p= 0.000 < 0.05 (Alpha level), proved that residuals were not normal (see table 4.25). Hence, normality test was failed by the residuals.

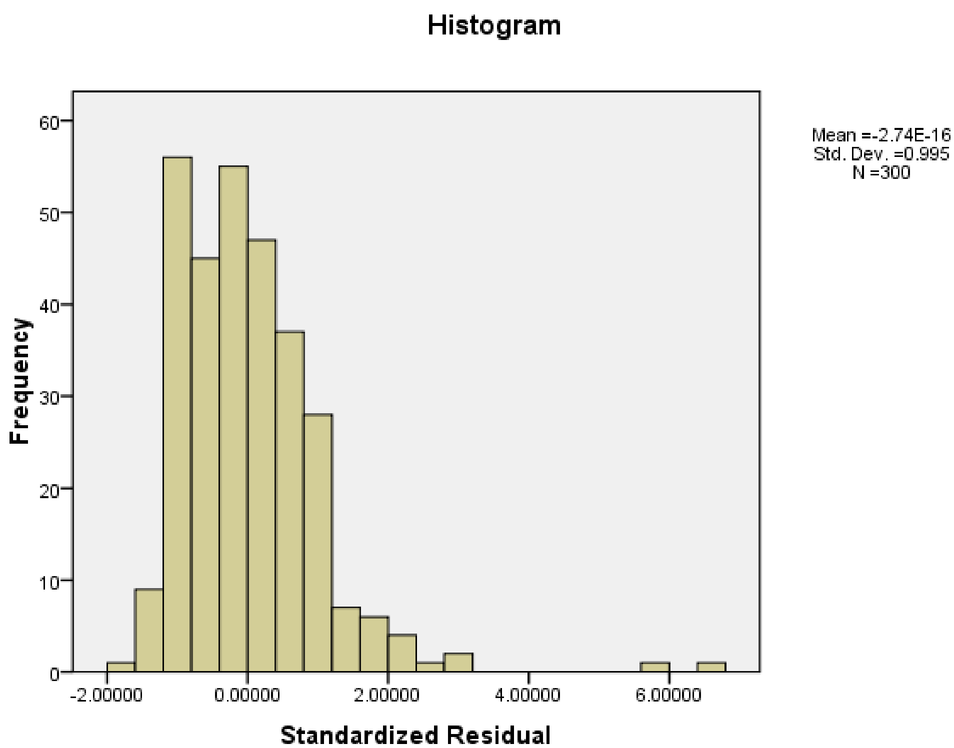


Figure 4.16 : Histogram

Table 4.25 : Kolmogorov- Smirnov Significance Value for Model 2

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Standardized Residual	.088	300	.000	.861	300	.000

a. Lilliefors Significance Correction

Constant Variance of Residuals

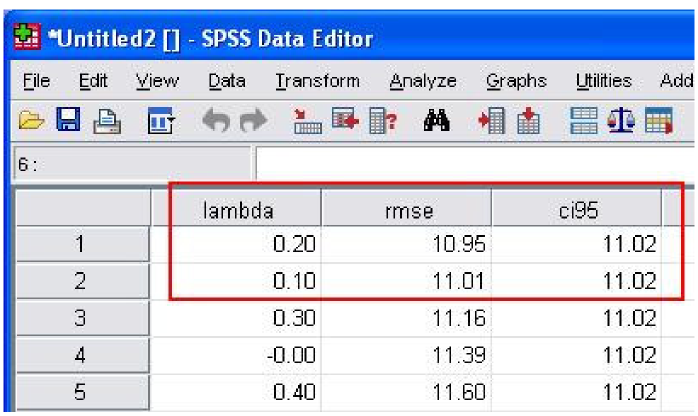
```
Run MATRIX procedure:

Regression SS
 190.1632

Residual SS
 3401.415

Total SS
 3591.578

R-squared
    .0529

Sample size (N)
  300

Number of predictors (P)
    3

Breusch-Pagan test for Heteroscedasticity (CHI-SQUARE df=P)
   95.082

Significance level of Chi-square df=P (H0:homoscedasticity)
    .0000

Koenker test for Heteroscedasticity (CHI-SQUARE df=P)
   15.884

Significance level of Chi-square df=P(H0:homoscedasticity)
    .0012

------ END MATRIX -----
```

Figure 4.17 : Koenker Test Significance Value

Since normality assumption was not met by residuals, Koenker significance value was used to test the constant variance of residuals. p= 0.0012 < 0.05 (Alpha level) for Koenker test for homoscedasticity proved that constant variance assumption was not satisfied (see figure 4.17).Hence, homoscedasticity test was failed by residuals.

Transformation of Dependent Variable

Since, the formal assumptions to report the multiple regression results were not met; transformation of dependent variable was done. Box Cox was used to find out the appropriate transformation of the dependent variable.



	lambda	rmse	ci95
1	0.20	10.95	11.02
2	0.10	11.01	11.02
3	0.30	11.16	11.02
4	-0.00	11.39	11.02
5	0.40	11.60	11.02

Figure 4.18: Box Cox Transformations

Box Cox suggested two possible transformations for the dependent variable (see figure 4.18). Following transformation was used for the analysis purposes.

Transformed Unit Value = (Original Unit Value)$^{0.2}$

Variable Selection

Interesting result was obtained when backward elimination method for variable selection was used (see table 4.26). So far area emerged as significantly correlated to the unit value as per the spearman's correlation. But when the transformation of dependent variable was done, area became non- significant and hence was removed from the model. For the interpretation purposes therefore, only minimum bus stop distance and minimum light rail station distance were used as the independent variables.

Table 4.26: Backward Elimination of Independent Variables

Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	AREA, MINRAILDIST, MINBUSDIST[a]	.	Enter
2	.	AREA	Backward (criterion: Probability of F-to-remove >= .100).

a. All requested variables entered.

b. Dependent Variable: Transformed Unit Value

Multiple Regression Analysis with Transformed Dependent Variable and Interpretation

Following model after variable selection procedure was used:

Transformed Unit Value = $\beta_0 + \beta_1$ (Minimum distance to Bus stop) + β_2 (Minimum distance to Rail station) + ε

Increase or decrease in the transformed dependent variable also resulted in increase or decrease in the original dependent variable respectively. Only the magnitude of this increase or decrease was different for the transformed and original dependent variable. Table 4.27 explains this phenomenon in detail.

Table 4.27: Transformed and Original Dependent Variable

	Unit Value	*Unit Value*	*Unit Value*
Original Dependent Variable (y)	3	10	40
Transformed Dependent Variable [yt = y ^ 0.2]	1.246	1.585	2.091
Untransformed Dependent Variable = yt^ (1/0.2)	3	10	40

P-value for this model was 0.000 < 0.05(see table 4.28). Anova table p value tested the hypothesis that there was no linear relationship between dependent and independent variables. From the p value obtained from the analysis it could be said that this hypothesis was rejected. Hence, the statistical model was significant and that linear relationship existed between dependent and independent variables.

Speaking in terms of the research variables, transformed unit value of parcels was found linearly related to the minimum bus stop distance and minimum light rail station distance. Since, this relationship existed; the multiple regression correlation value was also significant.

Table 4.28: Anova Significance Value for Transformed Model

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	22.771	2	11.386	100.409	.000[a]
	Residual	33.678	297	.113		
	Total	56.449	299			

a. Predictors: (Constant), MINRAILDIST, MINBUSDIST

b. Dependent Variable: Transformed Unit Value

Adjusted R- square for this model was 0.399(see table 4.29). So, 39.9 % variability in the transformed unit value of parcels was explained by the distance to the nearest transit points; bus stops and light rail stations.

Even though all independent variables were found to be significant predictors, they were not powerful. Because only 39.9% variability in the transformed unit value of parcels could be explained by these independent variables, whereas 60.1% of the variability was explained by some other relevant factors not considered in this research study.

Table 4.29: Adjusted R- Square for Transformed Model

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.635[a]	.403	.399	.33674

a. Predictors: (Constant), MINRAILDIST, MINBUSDIST

b. Dependent Variable: Transformed Unit Value

$\beta_1 = -0.356$, partial slope for the distance to the nearest bus stop (see table 4.30). This meant that as the distance to the nearest bus stop from a given parcel increased, transformed unit value associated with that parcel went down. This meant that if a parcel is located in close vicinity of public transit bus stop, its unit value, $/SF, will be more.

$\beta_2 = -0.106$, partial slope for the distance to the nearest light rail station (see table 4.30). This meant that as the distance to the nearest light rail station from a given parcel increased, transformed unit value associated with that parcel went down. This meant that if a parcel is located in close vicinity of the public transit light rail station, its unit value, $/SF, will be more.

Table 4.30: Population Parameters

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.980	.044		45.123	.000
	MINBUSDIST	-.356	.133	-.120	-2.667	.008
	MINRAILDIST	-.106	.008	-.619	-13.793	.000

a. Dependent Variable: Transformed Unit Value

Parameter estimates (see table 4.30) showed that independent variables; minimum bus stop distance and minimum light rail station distance were significant predictors of the transformed unit value of parcel. Minimum light rail station distance was more significant predictor of the unit value than was the minimum bus stop distance.

Following was the predictive equation obtained for transformed unit value. This model used the best estimates of the population parameters.

Predicted Transformed Unit value= 1.98 -0.356(Minimum bus stop distance) -0.106 (Minimum light rail station distance)

Predicted Un-Transformed Unit value= [1.98 -0.356(Minimum bus stop distance) -0.106 (Minimum light rail station distance)]$^{(1/0.2)}$

Following results were found when spearman's correlation with original dependent variable and multiple regression with transformed dependent variable were compared. As per the spearman's correlation, area was significantly correlated with the unit value, whereas when multiple regression using transformed unit value was done it was found that area was no longer a significant predictor of the transformed unit value.

Minimum distance to the bus stop was non-significantly correlated with the unit value as per the spearman's correlation. But multiple regression using transformed unit value showed that minimum distance to the bus stop was a significant predictor of the transformed unit value. This may be because of the transformation done on the dependent variable.

Results of this model showed that parcels that were located at a closer distance from the public transit points had higher unit values than parcels which were located far off from the public transit points. This model also confirms that distance measurements (parameters), one of the criteria to earn LEED credit for public transportation access, were significant predictors of the unit value of parcels.

CHAPTER V

CONCLUSION

Research Hypothesis

The general hypothesis which was tested in this research study was that statistical models considered were significant and that unit value of parcels could be predicted using the measurements (parameters) which are required to earn LEED credit. The confidence level to test Anova table p-values was set at 95%, i.e. alpha value of 0.05.Multiple regression Anova p- value tested the null hypothesis; that there is no linear relationship between dependent and independent variables.

For the first model following predictive equation was developed:

Predicted Transformed Unit value = 1.873 -0.015 (Num Bus stops) + 0.426 (Num Rail Stations) – 0.000002522 (area)

For this model Anova test p value was 0.000. So, the research hypothesis; the model was significant and that number of bus stops, number of light rail stations and area were significant predictors of the transformed unit value of parcel was accepted. This model presented significant relationship between the transformed unit value of parcels and the measurements required to earn LEED credit. Independent variables used in this model namely number of bus stops meeting LEED criteria, number of light rail stations meeting LEED criteria and area together accounted for 49.3% variability in the transformed unit value of parcels. These variables emerged as significant predictors but they were not powerful since 50.7% of the variation in the transformed unit value was explained by other factors which were not considered in this research study.

For the second model following predictive equation was developed:

Predicted Transformed Unit value = 1.98 -0.356 (Minimum bus stop distance) -0.106 (Minimum light rail station distance)

For this model p value of 0.000 proved that the model was significant and that minimum bus stop distance and minimum light rail station distance were both significant predictors of the transformed unit value. These independent variables together accounted for 39.9% variability in the transformed unit value of parcels. Variables of this model were significant predictors but they were not powerful since 60.1% of the variation in the transformed unit value was explained by other factors which were not considered in this research study. Backward elimination of variables showed that area was not a significant predictor of the transformed unit value for this model as opposed to the first model.

Conclusion

With the analysis done, it was found that meaningful predictive equations for the unit value of a parcel can be developed if appropriate independent variables are considered. Important and interesting results were found in terms of the parameters which are essential for a parcel to earn LEED credit for public transportation access. Overall, p values for models developed in this study were very encouraging. However, the adjusted R- square values vary dramatically for different parameters; namely number of transit points and distances to the nearest transit points.

For the first model, predictability of transformed unit value of a parcel meeting LEED criteria using number of transit points i.e. bus stops and light rail stations (which were located within the qualifying LEED distances) and area was calculated. According to results, an increase in the number of light rail stations led to the increase in the transformed unit value of a parcel. Whereas, number of bus stops which met LEED criteria for a given parcel had completely opposite effect over the transformed unit value of that parcel. That is, an increase in the number of bus stops meeting LEED criteria for a given parcel caused its associated transformed unit value to decrease. This phenomenon was important to note because both number of light rail stations and number of bus stops had completely different predictability of the transformed unit value of the parcel. Increase in one caused increase in the transformed unit value whereas increase in the other caused the transformed unit value to decrease.

This pattern may be particular to Houston because the light rail stations are concentrated more towards the center of the city i.e. downtown area, than being distributed all over the city. On the other hand bus stops are located all over the city. These different effects might be explained if there is a link between socio-economic status and transportation mode. This could be true if the bus system has been purposefully designed to transport people primarily from economically disadvantaged areas in the city. Further research is needed before a formal conclusion can be drawn.

Area was found to be a significant predictor of the transformed unit value. As the plot area was increased, parcel's transformed unit value went down.

For the second model, predictability of transformed unit value of a parcel using distance to the nearest transit points i.e. bus stops and light rail stations was calculated. This model suggested that distances to the nearest transit points both bus stops and light rail stations were significant predictors of the transformed unit value of parcel. According to the results as the distance to a nearest transit point from a parcel decreased, transformed unit value associated with that parcel increased. This model, as opposed to the previous model, was more consistent. Both the variables distance to nearest bus stop and nearest light rail station, behaved in similar fashion while predicting the transformed unit value. Area did not emerge as a significant predictor of the transformed unit value for this model as opposed to the first model.

Both the models suggested that LEED green building rating system influences the appraised value, dollars per square foot, of properties. This finding further implies that market considers the economic effect of the LEED rating system even if this assessment method does not explicitly include financial aspects in the evaluation framework. Findings of this research suggest that a sustainable feature of a site is related to the economic worth of a related land development project. This may provide encouragement for new sustainable land development projects since it may provide an economic incentive to the owners and developers. Developers will get encouragement to select a site located closer to mass transit networks, since results of the second model provide evidence to suggest that appraised value, dollars per square foot, of a site increases if it is located closer to the transit points. If the mass transit networks are located closer to a site, then occupants could be attracted to that site assuming they consider proximity to public transportation a benefit. This way they will get encouraged to use these local services rather than using their own automobiles. This could eventually help reduce the pollution caused by automobile use. This in due course will satisfy the intent of LEED public transportation access credit; to reduce pollution and land development impacts from automobile use (USGBC, 2005).

Directions for Future Research

The findings of this research study were both interesting and encouraging. However, this is the first investigation of its kind. Future studies will need to identify other factors that could explain more of the variation in the unit value of parcels. Also, findings of this research were based on the City of Houston. Future studies could focus on other cities.

Other sources, such as census data, probably contain information from which additional independent variables could be developed and tested. It is a speculation that bus transit network in the City of Houston was designed to provide transportation to lower income group to their work place. This may be one of the reasons for the inverse relationship between the unit value and number of bus stops that met LEED criteria. Household income for plots can be used as one of the independent variables. Sources of such data need to be studied carefully for potential variable material. When new independent variables are identified and data gathered, it can be collected to carry out further research.

Second order models including interaction between independent variables and non-linear models could be examined. Appropriate statistical tools should be used to produce meaningful equations.

For independent variables considered, logical grouping could be done. One of the possible groupings could be on the basis of land use pattern for example commercial vacant, residential vacant, industrial vacant, etc. This might prove to be useful to add new dimension and meaning to the existing findings.

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